WORKING GROUP ON THE BIOLOGY AND LIFE HISTORY OF CRABS (WGCRAB; outputs from 2020–2022 meetings)

VOLUME 5 | ISSUE 110

ICES SCIENTIFIC REPORTS

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International Council for the Exploration of the Sea
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H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 5 | Issue 110

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Recommended format for purpose of citation:

ICES. 2023. Working Group on the Biology and Life History of Crabs (WGCRAB; outputs from 2020–2022 meetings).
ICES Scientific Reports. 5:110. 123 pp. https://doi.org/10.17895/ices.pub.24720936

Editor

Carlos Mesquita

Authors

Ann-Lisbeth Agnalt • Kelly Bateman • Francis Binney • Samantha Blampied • Paul Chambers
Matthew Coleman • Hanna Danielsen • Ailsa Ellis • Jack Emmerson • Elena Guijarro
Ann Merete Hjelset • Natalie Hold • Carsten Hvingel • Idongesit Ikpewe • Alf Ring Kleiven
Alexandros Kokkalis • Johanna-Luise Kozák • Martial Laurans • Johanna Bjånes Marcussen
Guillermo Martin • Rosslyn McIntyre • Carrie McMinn • Alec Moore • Darrell Mullowney
Emily Roebuck • Samantha Stott • Jan Sundet • Oliver Tully • Martin Wiech • Fabian Zimmermann

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i Executive summary

The Working Group on the Biology and Life History of Crabs (WGCRAB) provides a forum for crustacean scientists to discuss common trends and challenges faced by these fisheries in different countries. The group's main objective is updating and providing data on landings, fisheries and biology of crab and lobster stocks, and discussing appropriate assessment methodologies that can be applied to these stocks in the ICES area.

Additional objectives include considering the impact of environmental drivers, diseases and pollution in the main commercial fisheries, reviewing research, and generating new knowledge on vital crustacean population biology. Examples were provided on fisheries for *Cancer pagurus* and *Homarus gammarus* in Ireland, France, Norway, Sweden, UK, Jersey and the Isle of Man, on *Chionoecetes opilio* in Norway and Canada, on *Paralithodes camtschaticus* in Norway, and on *Callinectes sapidus* in Spain. WGCRAB is progressing in evaluating and discussing assessment methods, sharing new knowledge and working toward collaborating projects.

For this cycle of the group's work, novel work on a disease affecting brown crabs, the presence of contaminants in crustaceans and the impact of introduced species were discussed. Several new stock assessments were proposed and presented for the first time for brown crab and European lobster, using mainly length-based methods or productions models such as SPiCT. WGCRAB recognises that further work must be carried out before achieving peer-reviewed assessments of the main ICES crab and lobster species.

Many crab and lobster fisheries lack scientific data and capacity to perform robust assessments of stock status and appropriate management advice. Moving forward, the group will continue to evolve towards implementation of stock assessments for all species considered and will assess new ways of working, such as, seeking assessment expertise from other ICES WGs, consider a longer meeting format, or creating a new assessment subgroup.

WGCRAB notes a common declining trend in CPUE and survey data observed in most brown crab fisheries, and recognizes that this message needs to be communicated widely and can be achieved with a collaboration paper to be produced in 2023. The group continues to collaborate and share data on a number of studies involving brown crab, snow crab and European lobster.

Whilst WGCRAB will move towards providing assessments of stock status for crustacean fisheries, it will continue to encourage participation from members who work on the biological studies that underlie stock assessments. The group will extend its focus into exploring genetics and stock structure of crab and lobster populations in the NE Atlantic and a new term of reference was proposed to deal with the quality of biological parameters used in stock assessments.

ii Expert group information

Expert group name	Working Group on the Biology and Life History of Crabs (WGCRAB)
Expert group cycle	Multiannual
Year cycle started	2020
Reporting year in cycle	3/3
Chair(s)	Carlos Mesquita, United Kingdom
Meeting venue(s) and dates	10-12 November 2020, Online Meeting (Webex), 21 participants [remote attendees]
	9-11 November 2021, Online Meeting (Webex), 26 participants [remote attendees]
	8-10 November 2022, Copenhagen, Denmark + Hybrid Meeting (Webex), 28 participants [physical attendees and remote combined]

1 ToR a) Information and data for crab and lobster fisheries by country

Full ToR a) Compile data on landings, discards, effort and catch per unit effort (CPUE) to provide standardised CPUE, size frequency and research survey data for the important crab and lobster (Homarus) fisheries in the ICES area, Atlantic Canada and Greenland. Maps will be produced to synthesise the data. Part of this data will be submitted to the ICES Data Centre.

This ToR was carried over to the next resolution (2023-2025) and will continue to be at the core of the WGCRAB work.

For most WGCRAB members, the main species of interest in the WG are brown crab and European lobster. However, work on other crab species such as spider crab, snow crab and king crab are also of interest. Data was presented on landings discards, effort, catch per unit effort, size frequency and research survey data for crab and lobsters species in Canada, France, Ireland, Norway, Sweden and UK (Scotland [including Orkney and Shetland], Northern Ireland, England, Wales, Jersey and Isle of Man). The WGCRAB notes a common declining trend in CPUE and survey data observed in most brown crab fisheries in Europe and it was felt that this message needs to be communicated. This will be achieved with a collaboration working document to be produced in 2023.

1.1 Brown crab (*Cancer pagurus*) in Scotland

1.1.1 Stock status of brown crab in Scotland

Brown crab is an important species for the Scottish fishing industry. Although the total weight landed is small relative to finfish landings, crustaceans generally attain high prices. The fishery has been long established and was traditionally an inshore mixed species creel fishery, prosecuted by small vessels. However, improved technology and the ability to store and transport live animals in the 1980s led to the development of an offshore fishery for brown crab. This, and the demand from new markets, resulted in a substantial increase in the Scottish landings (Mesquita *et al*., 2023). Total Scottish landings of brown crab ranged between 6,400 and 12,300 tonnes from 2012 to 2021 (Table 1.1). The principal fishing areas for brown crab in Scotland (Figure 1.1) are Orkney, East Coast, Hebrides and South Minch; landings from these areas accounted for over 60% of the total in 2021. Landings from the main fishing areas and also the offshore areas (Sule and Papa) decreased sharply in 2020 and 2021 (Figure 1.2). The majority of crabs fished in Scottish waters are landed in the third and fourth quarters of the year. Stock assessments have been carried out for brown crab since the 1990's. The latest assessment results for brown crab in Scotland are presented in Section 2.2.

Table 1.1. Annual Brown crab landings (tonnes) into Scotland by creel fishery assessment unit from 2012 to 2021.

Assessment unit	Year									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Clyde	118	95	110	118	74	173	194	257	101	126
East Coast	1214	1271	1306	1200	1609	1768	1774	1714	1273	1214
Hebrides	1997	2130	2667	2218	2391	1820	1427	1112	778	717
Mallaig	70	7	17	11	26	8	24	49	32	36
North Coast	514	571	538	1016	1046	869	599	433	275	233
Orkney	1694	1906	1959	2038	2463	2444	2087	1880	1416	1162
Papa	828	936	1239	930	888	786	618	525	392	324
Shetland	478	605	666	458	282	475	551	590	450	577
South East	447	470	396	457	620	633	594	570	348	444
South Minch	1158	934	1271	753	1089	1189	1297	1652	1035	898
Sule	1611	1492	1704	1630	1298	950	691	508	245	225
Ullapool	687	439	401	208	318	440	435	343	159	179
Outside Units	75	34	32	51	37	44	177	179	131	276
Total	10890	10891	12306	11087	12141	11600	10467	9813	6634	6411

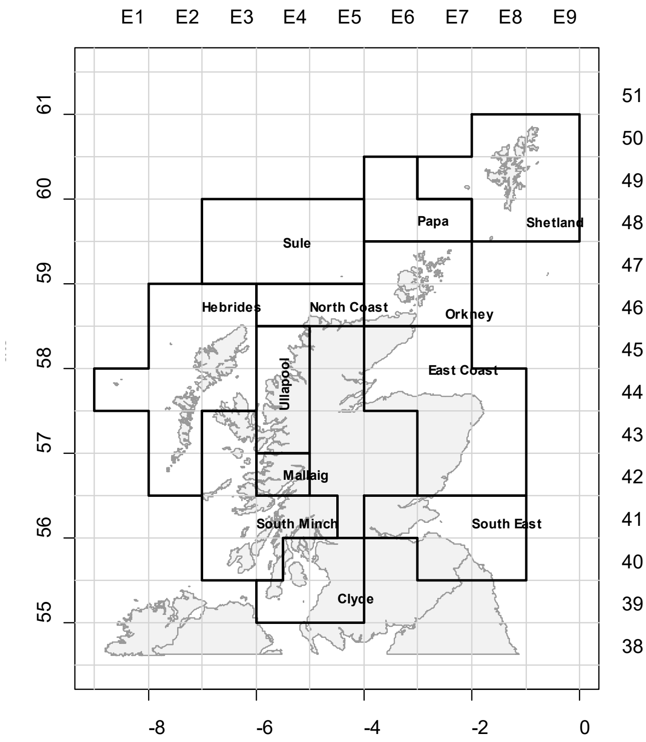


Figure 1.1. Crab and lobster creel fishery assessment units in Scotland.

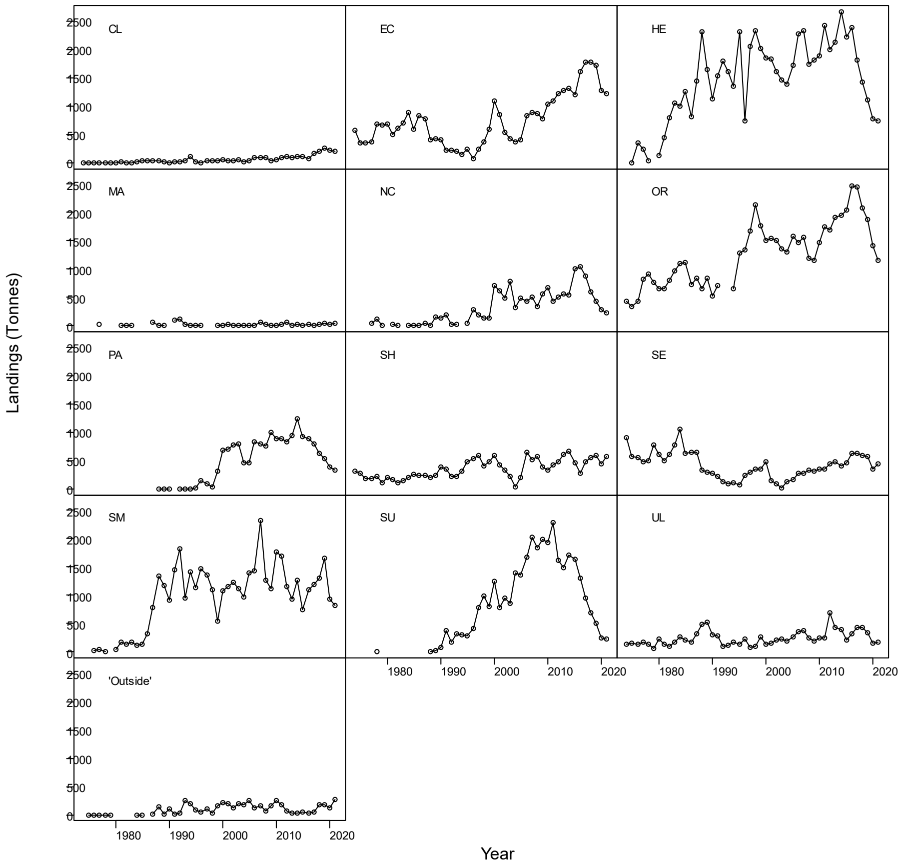


Figure 1.2. Annual brown crab landings (tonnes) into Scotland by fishery assessment unit. 'Outside' relates to brown crab landed outside the creel assessment units; see Figure 1 for area locations.

1.1.2 Use of survey data to assess the distribution of brown crab around Scotland

Brown crab is a widely distributed crustacean that occurs around the British coastline supporting important commercial fisheries. The habitat preferences of brown crab around Scotland are poorly documented and for the purposes of stock assessment, the species is considered data-poor. Based on an analysis of dredge and trawl surveys taking place in the North Sea and west coast of Scotland (2008-2021), the spatial distribution of brown crab was described and abundance and recruitment indices for the species were developed (Mesquita *et al.*, 2021; Mesquita *et al.*, 2023). Geostatistical methods and generalized additive models (GAMs) were used to model catch rates in relation to a number of explanatory variables (depth, distance to the coast, sediment type and year). The dredge and trawl abundance indexes were correlated showing a similar trend of increasing catch rates in the early years of the time series up to 2016 and a subsequent reduction. The recruitment index showed a gradual increase in captured juvenile crabs up to 2014 followed by a steep decrease with 2020-2021 being the lowest values estimated. The recent brown crab landings reduction in Scotland coincides with a decrease in the abundance and recruitment indices calculated for the species. While the study areas of these surveys do not entirely match the brown crab habitat, information from these additional data sources may provide an indication of abundance and recruitment trends for the species. The derivation of robust indicators of stock abundance will contribute to the stock assessment of this species and enable the provision of improved fisheries management advice for brown crab around Scotland.

1.2 Brown crab (*Cancer pagurus*) in England

Trends in official reported landings (tonnes) and effort (days fished) are reported for brown crab *Cancer pagurus* in England. There are five Crab Fishery Units (CFU) that have been defined for England (Figure 1.3). These units are based upon the understanding of larval distributions and development, hydrographic conditions and distribution of the fisheries. Each CFU encompasses waters covered by international, national and local legislation, which may be different within each region.

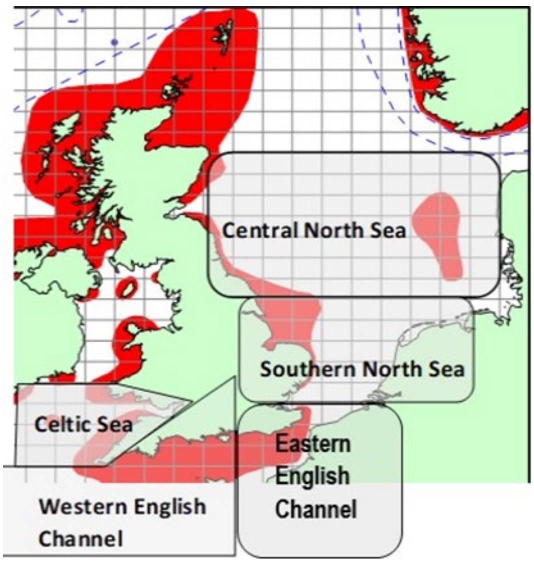


Figure 1.3. Crab Fisheries Units (CFUs) around England.

1.2.1 Overall Landings trends

Figure 1.4 presents the total official landings data, which pertains to all English and Welsh vessels landing anywhere, and all landings into England and Wales from other GB registered vessels. The overall landings appeared relatively constant between 2006 until 2011 then increased until 2018. The spring of 2018 saw extreme cold weather throughout the country and crab began to appear in pots very late in the season. In 2020-21, Covid restrictions and adjusting to the new requirements for exporters following the UK's exit from the EU affected fishing effort, prices and markets for crab. A mass mortality event occurred in autumn 2021 in the North Sea, the cause of which remains uncertain.

Crabs are landed around the whole of the English coast, with the highest numbers landed around Yorkshire followed by South Devon and West Cornwall (Figure 1.5).

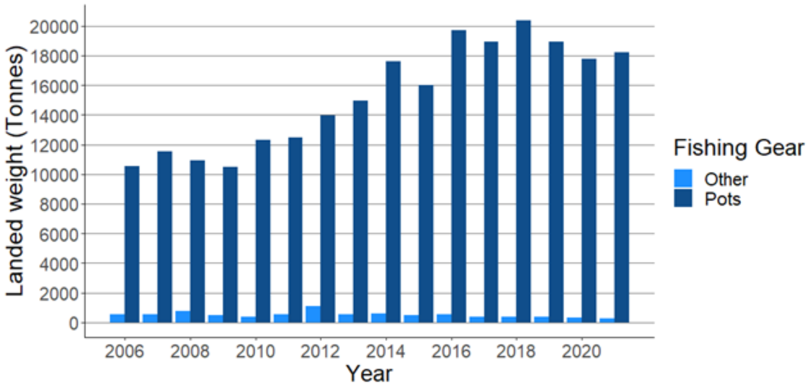


Figure 1.4. Official landings for UK E&W. Dark blue= landings from pots; light blue= landings from all other gear types.

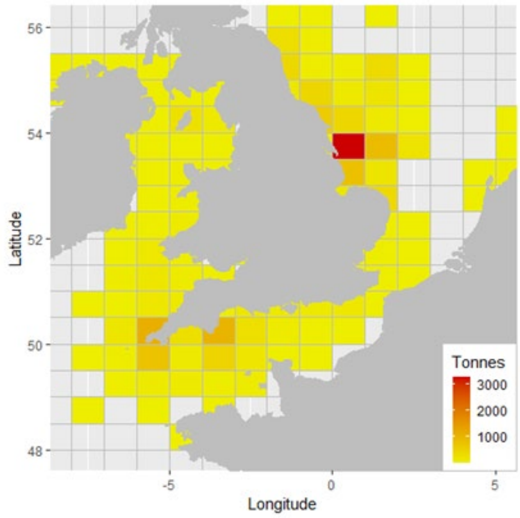


Figure 1.5. Landings per ICES rectangle for 2021.

Landings in tonnes and effort in days at sea is reported for each FU. Reported landings and fishing effort increased substantially following the introduction of Buyers and Sellers legislation and the Restrictive Shellfish License Scheme in 2006 when submission of monthly shellfish returns by fishers was required. Since this period fishing activity data are thought to be generally more reliable but the integrity of the time series, especially fishing effort, is uncertain.

Landings have decreased in all regions in the last three years with the exception of the Southern North Sea, where landings have increased steadily from 2010 (**Figure 1.6**). Landings peaked in 2018 in the Central North Sea and Celtic Sea, with a longer-term decline evident in the Eastern and Western English Channel. Effort (days fished) has risen slightly over the last decade in the Southern North Sea, and has fluctuated with no general trend in all other regions.

Low landings are now a cause of concern, particularly for inshore vessels in the Western English Channel who are limited by area and ground availability to maintain their catch rates. There has been an increase in the last few years of vivier vessels fishing large numbers of pots.

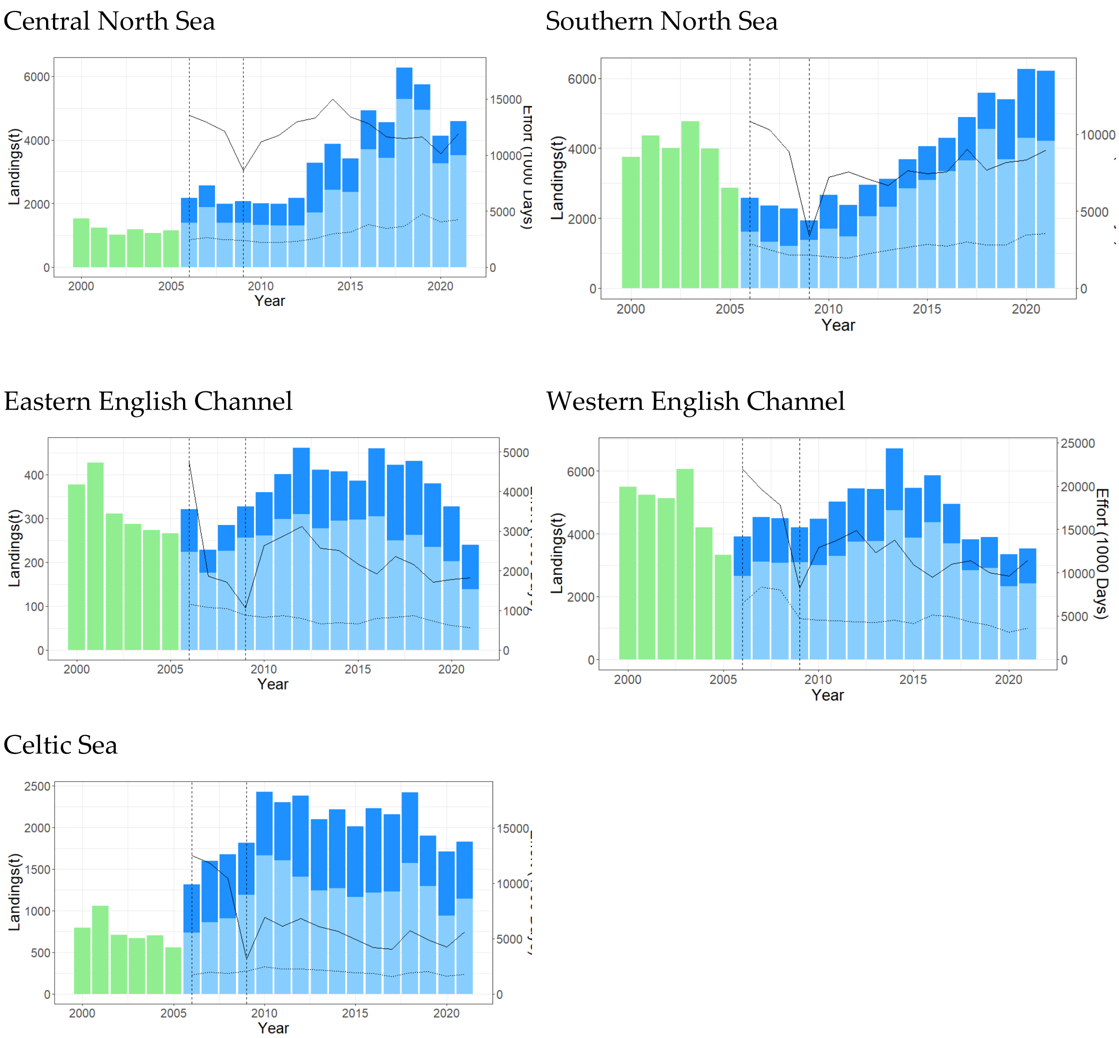


Figure 1.6. Landings (bars) and effort (lines) for the =<10m fleet (dark blue/solid line) and the >10m fleet (light blue/dashed line). Landings for 2000 to 2005 have been combined. Note: changes in recording of landings occurred in 2006 and 2009.

1.3 Brown crab (*Cancer pagurus*) in Northern Ireland

Annually, around 125 Northern Ireland (NI) registered vessels fish using static gear. Most of these vessels are under 10m in length. Whilst the fishery around NI is mixed, the main catches show spatial trends. Along the Antrim coast, the primary catch is lobster; in north Down velvet crabs make the highest proportion of catches and in south Down brown crab account for the majority of landings.

Brown crab has the greatest landings of pot caught species in NI. For brown crab, there is no TAC or quota. There is an MLS of 150mm, which was introduced in January 2022; there is a ban on landing berried brown crab; no iVMS is available for < 12m vessels other than in Strangford Lough; recreational legislation exists which limits unlicensed fishers to five pots and landings of five brown crab and one lobster per day.

In 2021, 569.8 tonnes of brown crab were landed by NI registered vessels from the ICES rectangles bordering NI (37E3, 37E4, 38E4, 39E3 and 39E4). This is a reduction in landings from a peak in 2012 (1095 tonnes), and the second lowest landings recorded over the time series (2006-2021) (Figure 1.7).

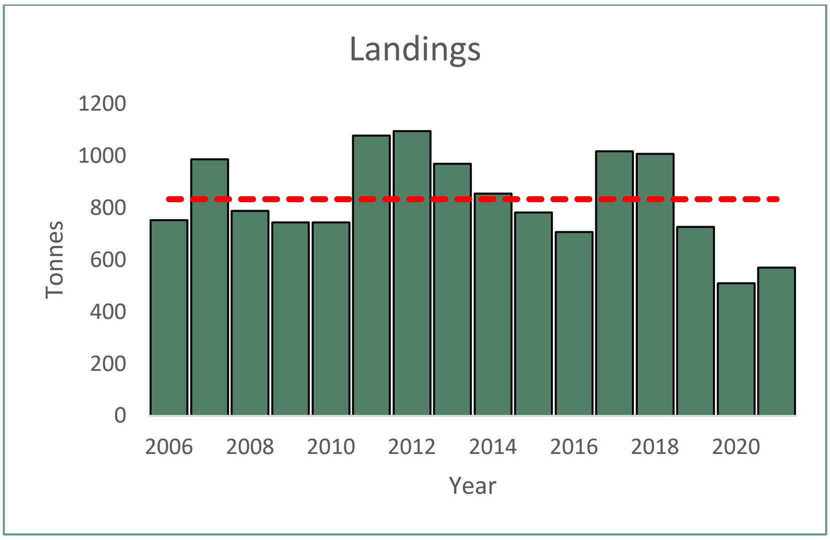


Figure 1.7. Landings of brown crab from ICES rectangles 37E3, 37E4, 38E4, 39E3 and 39E4. Red dashed line represents average overtime.

Analysis of the effort placed on the crab fishery shows an overall increase in the number of pots used to land brown crab since 2006 (however, this has decreased in 2020 and 2021). This increase is primarily driven by increasing effort placed in ICES rectangle 37E4. The landings per unit effort (LPUE) shows a decreasing trend for brown crab; again, most noted in 37E4.

The Agri-Food and Biosciences Institute (AFBI) run an observer programme for the NI pot fishery, with an average of 19 commercial trips sampled per year. However, in 2022 the number of trips sampled has increased through the Enhanced Inshore project (funded through EMFF) which allowed for a dedicated inshore observer. Observers collect information on the temporal and spatial attributes of the fishery, plus biological information on the species caught.

A length-based model has been developed as an indicator of crab and lobster health, using the length data of landed crabs and lobsters collected during observer trips. The model shows that for brown crab both males and females are below Lopt.

AFBI produce inshore advice sheets, which set out fishery trends and reference points for all the inshore species. For brown crab in 2023, the advice is that landings should be reduced in line with the declining LPUE trend and size indicators of crab. The full advice sheet for brown crab is available at:

https://www.afbini.gov.uk/sites/afbini.gov.uk/files/publications/Brown%20crab%20advice%202023.pdf

1.4 Brown crab (*Cancer pagurus*) in the Isle of Man

1.4.1 Fishery update

The brown crab fishery in the Isle of Man territorial sea has typically produced between c.400 and c.550 tonnes each year over the past decade. The year of 2018 was exceptional for the fishery, producing over 575 tonnes, whilst 2019 saw harvest levels return to previous levels (~475 tonnes). In 2022, landings and effort increased to 546 t and 377,000 pot-lifts, equal to an increase of +15% and +4% relative to 2021 respectively. The fishery is historically an autumn fishery, with this trend continuing in 2022, with the highest landing per unit effort LPUE recorded in October.

The Isle of Man fishery is currently monitored and assessed through its statutory logbooks scheme, recording daily effort and landings per species for all license holders. This fishery dependent data is used to produce standardized landing per unit effort (LPUE) through general additive modelling. Standardized LPUE data were presented at WGCRAB 2022 for Brown Crab. The use of standardised LPUE enables the effect of vessel, seasonality of landings, and area of operation and capture of other species to be accounted for. In this instance despite a marked increase in landings, a decline in standardised LPUE was recorded in 2022 (**Figure 1.8**). This decline follows an increase in LPUE in 2021 but is now following the pre-covid trend of decline LPUE. Similar to lobster fishery data, there are issues with reporting effort for 'mixed' crab and lobster activity. However, the fisheries are becoming increasingly distinct (seasonally and temporally). Following the implementation of inshore vessel monitoring systems (iVMS) from April 2023 more precise spatial and temporal information can be added to logbook data and incorporated in the analysis, increasing our understanding and interpretation of long-term trends. In addition, Bangor University is investigating stock assessment techniques that can be used to further analytically assess brown crab stocks in the Isle of Man territorial sea.

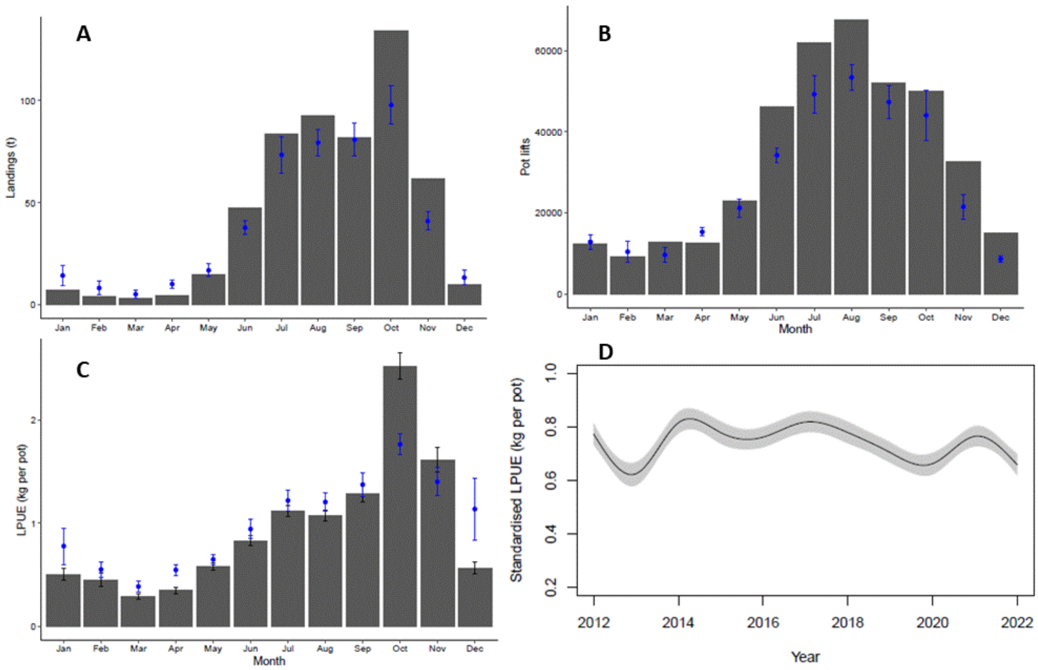


Figure 1.8. Brown Crab A) Monthly landings declared in the Isle of Man Territorial Sea throughout 2022 (greys bars) relative to mean values (and standard error) over the reference period 2015 – 2019. B) Monthly pot lifts declared in the Isle of Man Territorial Sea throughout 2022 (grey bars) relative to mean values (and standard error) over the reference period 2015 – 2019. C) Monthly variation in LPUE (Kg/per pot lift) throughout 2022, grey bars relative to mean values (and standard error) over the reference period 2015 – 2019. D) Standardised long term GAM LPUE trend (2012 – 2022) for the Isle of Man territorial sea.

1.4.2 Integrating gear-in gear-out and mobile technology in the IOM brown crab fishery

Most crab and lobster stocks are unassessed and there is a significant deficit in the resolution of fisheries-dependent data that could be used to track indicators such as spatial distribution of effort, and landings-per-unit-effort.

Moreover, a significant proportion of the fleet (particularly 'inshore' day-boats that operate in the 0-12 nm zone), target crab and lobster stocks concurrently within the same ICES statistical rectangle. Shift effort and fishing patterns between the two species by means that are not documented in logbooks (e.g. targeting specific habitat types and locations, using specific baits, soaking pots for longer/shorter periods). Furthermore, it is well known that LPUE data within baited-pot fisheries are highly variable and effected by abiotic factors of the marine environment, as well as behavioural aspects of conspecific interactions within and around traps. Fisheries-dependent LPUE data is therefore to be used with caution, unless its resolution and scope can be enhanced to observe these additional aspects.

In the Isle of Man, Bangor University has deployed an Enhanced Electronic Reporting System (EERS) that uses gear-in gear-out technology together with mobile reporting and user-input to record high resolution and accurate LPUE data. The data shows that geoposition, sea-bottom-temperature and catch of *H. gammarus* has a significant effect on *C. pagurus* LPUE, all of which should be controlled for and monitored alongside commercial LPUE (particularly in the inshore 0-12 nm area) in order to accurately model and interpret trends in fisheries-dependent LPUE, before using the indices as an indicator of stock health.

1.5 Brown crab (*Cancer pagurus*) in Jersey

1.5.1 The brown crab fishery in Jersey

During the last three-year WGCRAB cycle, Jersey has continued to monitor its crab stocks through both landings and effort data, and independent surveys. This report summarises the key information pertaining to the brown crab fishery and provides an update on landings trends.

In Jersey, there is no TAC or quota for brown crab. Pot fishing in Jersey is currently regulated using a Minimum Landing Size (MLS) of 150 mm carapace width (no max landing size), a pot cap (typically 1000 pots per vessel), and a recreational daily bag limit of 5 crabs per fisher/vessel. VMS is available for vessels >12 m in length; vessels under <12 m will be required to have iVMS by January 2024.

The brown crab (*Cancer pagurus*) forms a key part of Jersey's commercial fishing industry. Since at least the late nineteenth century it has been targeted by Jersey vessels, though primarily caught in the pots also used to target lobster. Most brown crab landed in Jersey, around 90%, has traditionally been exported to Europe via France either as direct landings from Jersey fishing vessels or via the islands fish merchants. Jersey waters are also fished by vessels from Normandy and Brittany and were, until 2021, subject to joint management through the Bay of Granville Agreement (GBA). Data provided by Ifremer suggests that the brown crab fishery is dominated by Jersey vessels.

Jersey has a commercial fishing fleet consisting of circa 135 (as of 2020) vessels with most being <10 metres in length. Jersey's fleet uses a range of fishing methods with potting being the dominant metier. Although a variety of pot types are used, parlour pots account for nearly 90% of total fishing effort. Parlour pots are an efficient method of capturing crab and lobster as once an individual enters the second holding chamber it is not able to exit again, and it is for this reason that parlour pots are excluded from two areas of offshore reef that are key fishing grounds for crab and lobster. Two No Parlour Pot Zones (NPPZs) are currently in place, one at Les Minquiers to the south of Jersey that was established in 2007 and another to the northeast of Jersey at Les Écréhous was established in 2017 (Figure 1.9).

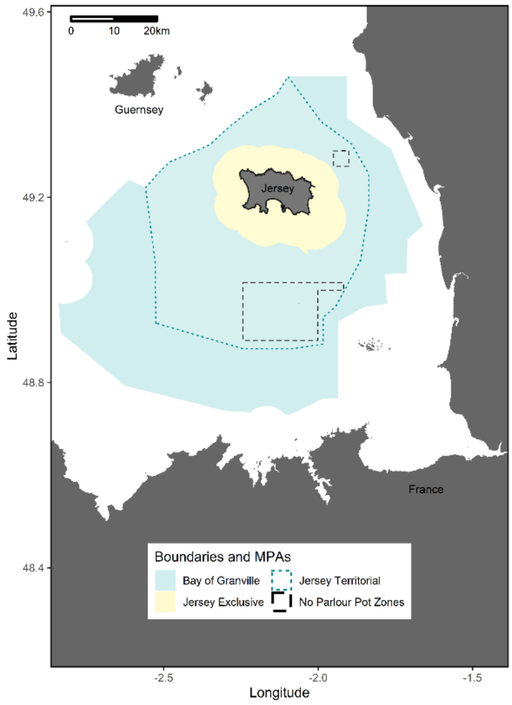


Figure 1.9. Location of No Parlour Pot Zones (NPPZs) in relation to Jersey and France.

1.5.2 Catch data

For the Jersey fleet brown crab landings (kg) peaked in 2012 (507,408 kg) but have since been declining (Figure 1.10). This decline was further exacerbated in 2020 and 2021 due to Brexit and covid, which saw brown crab landings to drop to around 100,000 kg.

There are various ongoing monitoring programs being conducted by the Marine Resources team to better understand long-term changes in spider crab stocks. These datasets include:

- Commercial logbook data (2007-Present)
- Annual spring potting studies (2004-Present)
- Autumn potting studies in Marine Protected Areas (2018-2020)
- Quayside measurements (2019-present)

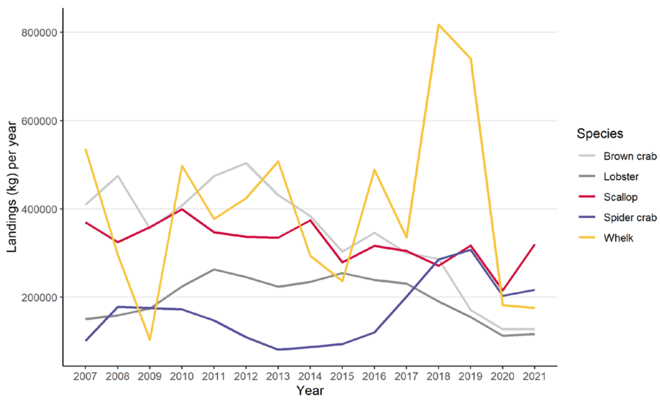


Figure 1.10. Landings (kg) per year for the five key fisheries between 2007 and 2021.

The commercial fleet have submitted daily effort and catch statistics since 2007 in the form of logbooks. These logbooks are received quarterly and are mandatory for all licenced Jersey fishing vessels. Weights are in KG and are recorded for one of six zones. Effort is recorded in pot lifts and the type of pot must be recorded e.g. inkwell, parlour or D Pot. Marine Resources holds catch statistics going back to the 1960s but both the makeup of the fleet, its fishing grounds and the quality of the data have varied over the years so consistent records on which management decisions can be based are considered to start from 2007.

The number of pots used across the Jersey pot fishery has been decreasing since 2017 which is driven by the decline in use of parlour pots (Figure 1.11). Landings per Unit Effort (LPUE) for brown crab has steadily declined since 2012 and was lowest in 2021 at just 9.8 kg per 100 pots (Figure 1.12). The overall effort in terms of pot lifts peaked in 2017 and has since declined, with the lowest number of pot lifts recorded in 2021 at around 1 million pot lifts.

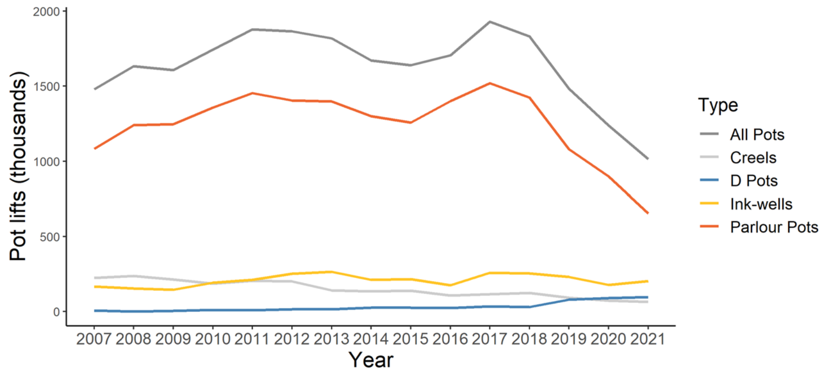


Figure 1.11. Number of thousand pot lifts for different pot types used per year in the Jersey commercial lobster fishery between 2007 and 2021.

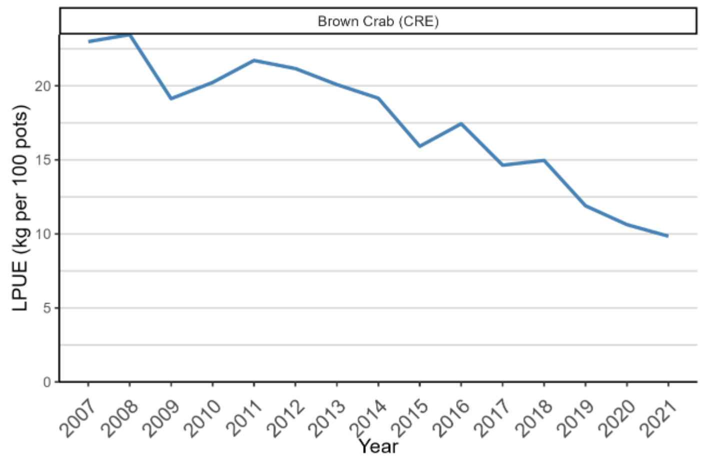


Figure 1.12. LPUE (kg per 1000 pots) for brown crab between the years 2007 and 2020.

1.5.3 Annual potting surveys

Since 2004, Jersey has conducted an annual sampling program during spring using adapted parlour pots to capture and record crustacean abundances each year, including brown crab. Thirty pots are fished five times across May and June each year in three locations considered representative of the fishery (Figure 1.13). The pots are of the parlour design and do not have escape gaps. The pot mesh is also smaller than current parlour pots to capture and record juvenile crustaceans. Following a 48-hour soak, the pots are recovered and all shellfish are measured. In respect of spider crab, the following measurements are taken: carapace length, carapace width, carapace depth, sex, berried status, damage and disease.

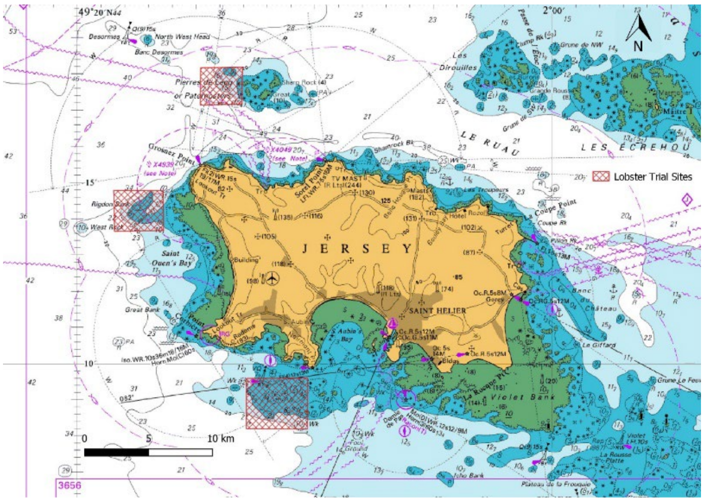


Figure 1.13. Locations of potting trial survey areas (in red), in realtion to the island of Jersey.

The mean number of brown crabs caught per pot peaked in 2014 and have been decreasing since. In all years, mean number of undersized brown crabs was greater than sized (Figure 1.14). Figure 1.15 shows the size distribution of brown crab <MLS was stable but the frequency of all size classes <MLS decreased, whilst both the frequency and distribution of sizes of brown crab >MLS decreased over time.

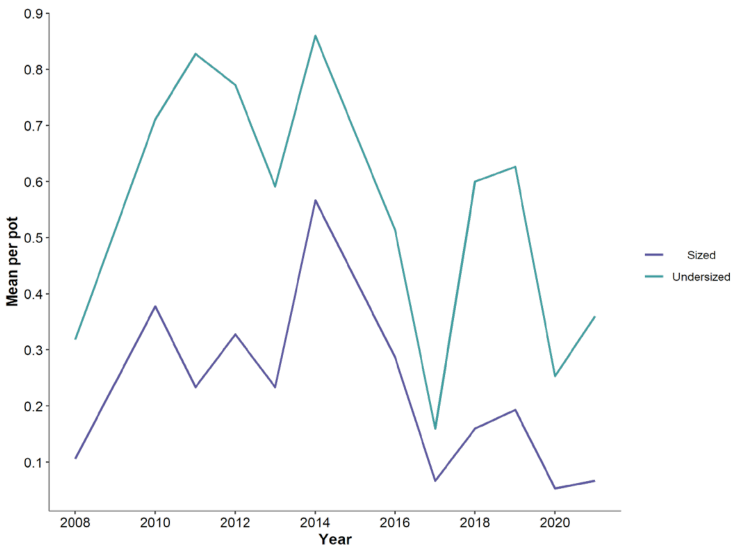


Figure 1.14. The size distribution of brown crabs caught in the annual trials between 2008 and 2021.

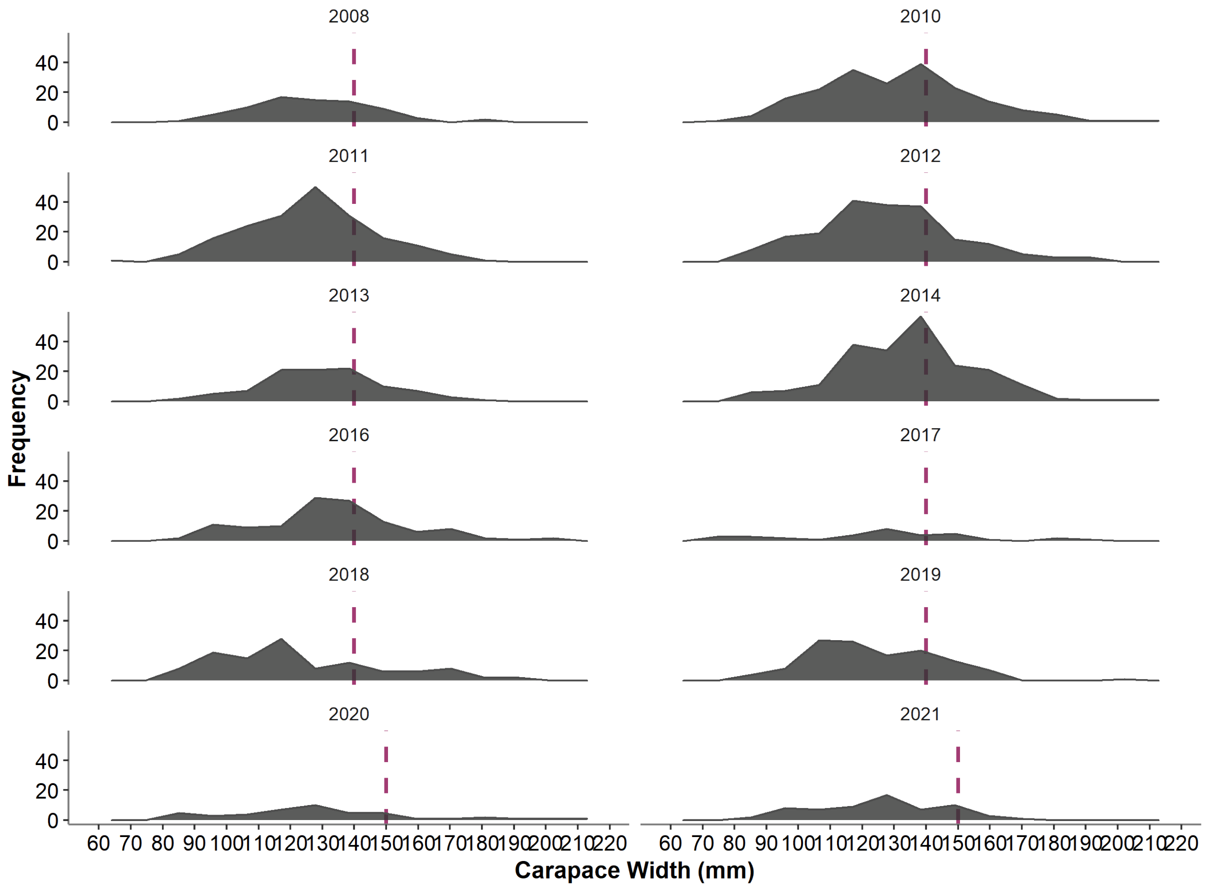


Figure 1.15. The size distribution of brown crabs caught in the annual trials between 2008 and 2021.

From 2018, an additional potting survey (during autumn) was introduced at Les Écréhous and Les Minquiers as part of a PhD project to assess the commercial crustacean populations at the offshore reefs. Pots were set across three separate management areas: Marine Protected Areas (where mobile gear is excluded); No Parlour Pot Zones, and Open fishing areas. The results showed brown crab to be in overall low abundance across locations, treatments and years. The full study is available on request.

1.6 Brown crab (*Cancer pagurus*) in Ireland

Targeted fisheries for brown crab in Ireland developed during the 1960s. The fishery developed off Malin Head in Donegal and along the Donegal coast and, to a lesser extent, on the south coast during the 1970s. The Malin Head fishery accounted for 25% of national landings during the 1980s. The offshore fishery developed in 1990 and by the mid-1990s had fully explored the distribution of brown crab on the Malin Shelf. This stock, which extends from Donegal to the edge of the continental shelf, is the largest stock fished by Irish vessels. Crab stocks off the southwest and southeast coasts are exploited mainly by Irish vessels <13 m in length inside 12 nm.

ICES (WGCRAB) has identified stock units for the purpose of assessment (Figure 1.16). On the Irish coast, these units are identified from tagging data, distribution of fishing activity and larval distribution.

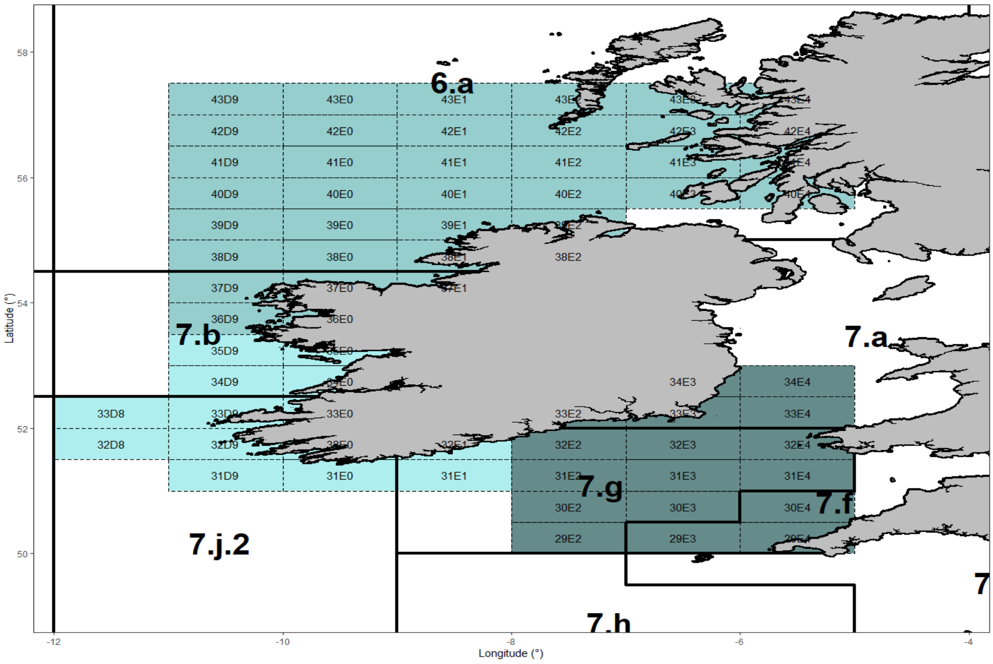


Figure 1.16. Brown Crab Stock limits around the coast of Ireland.

Over the past three-year cycle of WGCRAB, Ireland, has completed an assessment of brown crab stocks and determination of MSY reference points using the Surplus Production Model in Continuous Time (SPiCT) for the Malin Shelf stock and that accounts for international landings from the stock. A brief context of crab stocks around Ireland is given below, including the data sources available and the biomass index standardization process carried prior to the SPiCT assessment (the stock assessment method and results are detailed in section 3.1). The summary below provides a general overview of the work carried over the past three years focusing on brown crab. The assessment is currently being updated to include landings and indices for 2022.

1.6.1 Landings

Landings data from Irish, Northern Irish and Scottish vessels fishing for brown crab in the Malin Stock were collated after contacting the respective international institutions. The time series available for each country varies substantially as seen in Figure 1.17 (left), as well as the quality of the data reported.

A complete view of the landings from the three countries is available from 2002 onwards. Northern Irish data before this year was not accessible. Throughout the time series, Irish vessels land the largest proportion of Brown crab in the area. Peak of landings occurred in 2004 at almost 11000 tonnes. The peak in Irish landings observed in this year did not occur in the Scottish or Northern Irish time series. Scottish landings have remained relatively stable from the early 90's, whereas Northern Irish landings show a continuous increase with exception of 2019.

Reconstruction of the NI landings prior 2002 was suggested during model development to inform SPiCT model that potentially more landings were occurring in the area than reflected by the data reported. A longer time series of landings could aid in model fitting and diagnosis. A Generalized Linear Model (GLM) framework was suggested to hindcast these landings (Figure 1.17, right). Given that NI landings represent a small portion of the total landings in the area, the results were considered appropriate.

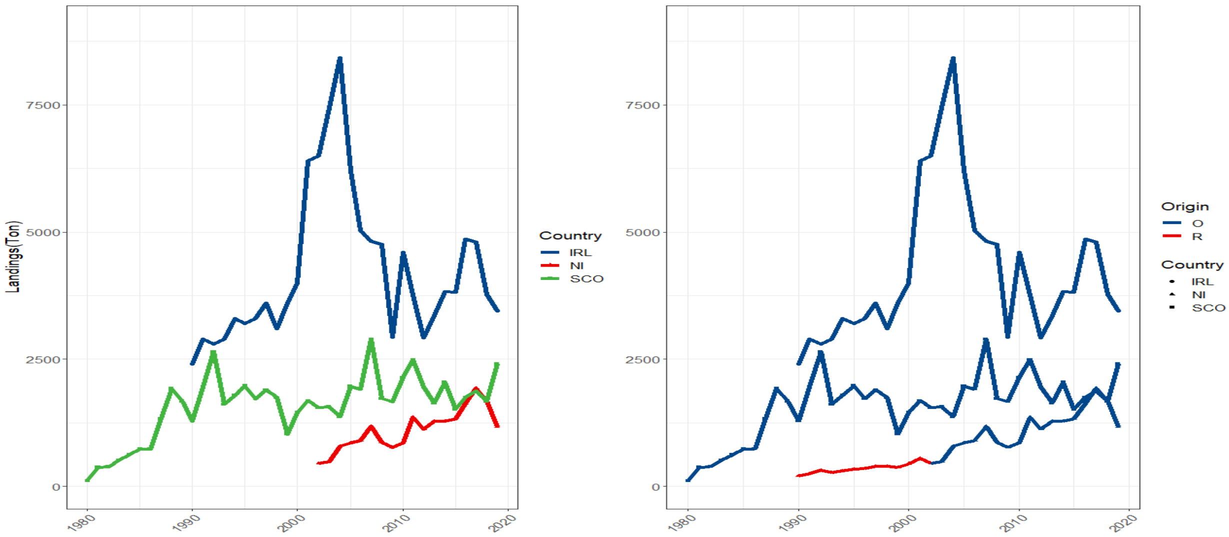


Figure 1.17. Left: Time series of landings (tonnes) of brown crab in the North West of Ireland by Irish (IRL), Northern Irish (NI) and Scottish (SCO) vessels and right: reconstructed NI landings (red) after implementing a GLM framework.

1.6.2 Biomass indices

There is no current scientific survey in the area to estimate brown crab biomass. Commercial catch rate data can be used as a true index of abundance if the effects on catch rates of factors (co-variates) other than changes in crab abundance can be accounted for. This process is usually referred as catch rate standardization. Among the methods commonly used to remove these effects are Generalised Linear Models (GLM's) and Generalized Additive Models (GAM's).

The methodologies used for the standardization of the two available indices used in the Malin Stock assessment go beyond the scope of this document. A brief description of the data sources and the modelling procedures is described below. Although both indices are in terms of Landings per Unit of Effort (LPUE), mortality in brown crab associated with discarding is known to be negligible.

1.6.3 Sentinel Vessel Programme

The primary indicator of stock status for the Malin Stock consists of daily catch rates collected as part of the Sentinel Vessel Programme (SVP; a self-sampling scheme around Ireland) or earlier versions of it. Daily landings per unit of effort (LPUE) for the period 1996-2020 were collated. Data on discards are also available but are less often reported and were not included. Additional trip information includes number of pots, soaking times, bait used and landings price. An extensive data exploration was carried before any model implementation to identify potential issues, such as outliers (in both landings and effort) or missing data.

Only trips targeting crab were used in the standardization analysis to reduce the variance in the LPUE estimates that would result if vessels targeting lobsters with a crab by-catch were included. When the target behaviour was not recorded for a particular vessel or trip, it was assumed that vessels above 8m in total length tend to target brown crab. Data was also limited to soaking times below 30 days (93.7% of the data).

A gamma GAM was applied to the raw SVP LPUE data using a set of covariates including an effort as number of pots offset, year fitted as fixed effect, a smoothing effect for Soak Days, to account for potential non-linear relationships between catch and soak time, and a single random effect ("iid") for Vessel ID, to account for potential intra-correlation in vessel observations.

The resulting index of abundance was based on the predictions of the fitted model for standard values of the covariates. Thus, standardized estimates were obtained for each year based on, the mean of the effort and the mode of soak days (2 days). The vessel effect was removed from the predictions (Figure 1.18).

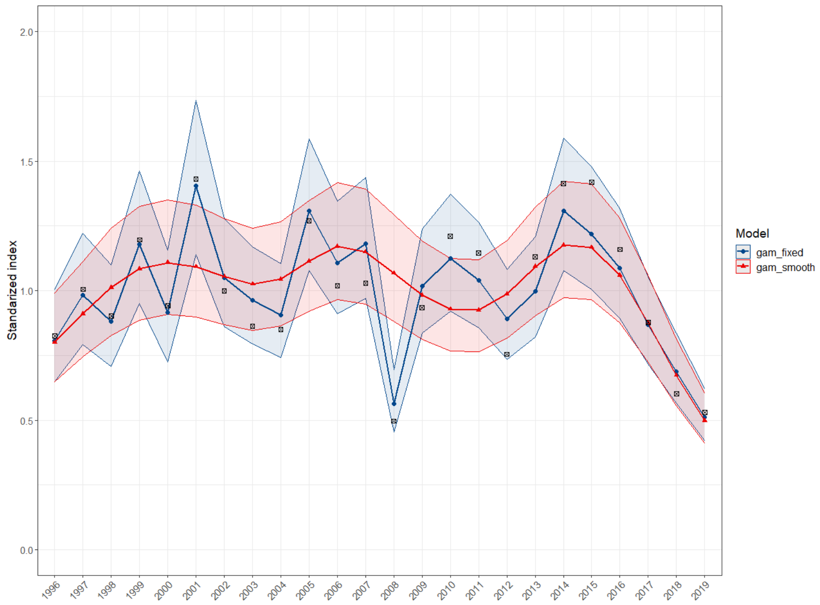


Figure 1.18. Standardized index of crab abundance from the SVP programme after applying two different GAM model formulations (Gam_fixed: Year as fixed effect, GAM_smooth: year as spline). Shaded regions indicate approximate 95% confidence intervals. Annual mean raw.

Both GAM indices of abundances show a relative increase in LPUE in the first 10 years of the time series (Figure 1.18). Data prior 2005 however, is considered very unreliable as a limited number of vessels were participating in the sampling scheme. A sharp decrease in the standardized LPUE occurred from 2014 onwards in both models. GAM_fixed (a fixed categorical year effect), shows substantially more inter-annual variability compared to GAM smooth; the splines in the second model smooths differences across years. In GAM_fixed, 2008 appears as a clear outlier in the standardized index. The limited sampling in this year for the Malin stock (3 vessels only compared to 9-15 vessels over the time series) are likely to be causing this outlying estimate.

1.6.4 Offshore Vivier Index

Landings per unit of effort, as kilograms of Crab per pot, were recorded by the Irish Offshore crab fleet from 1991-2006. Information of catches were georeferenced at haul level (Latitude/Longitude) and included effort as number of pots and soaking time in days.

A total of five different vessels have operated in the fishery during this time period, although active vessels have changed over time as the fishery developed. Outlines were identified and removed, as well as hauls with missing information in any of the covariates. Hauls deeper than 200m were removed from the dataset (4.9%), as it is uncommon that fishing events targeting crab set lines of pots beyond this threshold. Similarly, soaking times beyond 11 days were removed from the data (2.06% of the hauls), as these were only common during the expansion period of the fishery and then standard practices were limited to two-three days (69% of the hauls). Observations outside the most common geographical range of the fishery were also removed (0.22%), as these were clearly identified and rare, helping in the delimitation of the area for the spatial models. The final dataset included a total of 17954 fishing events (Figure 1.19).

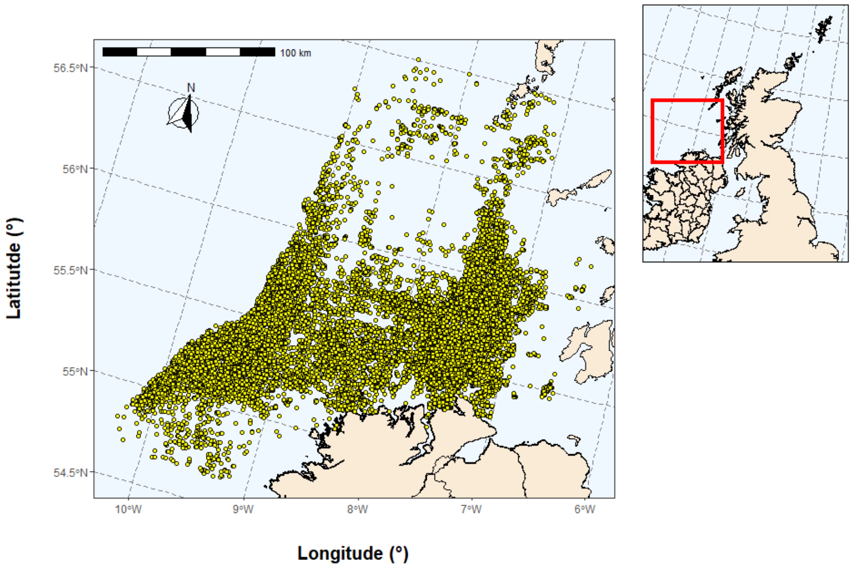


Figure 1.19. Hauling event locations from the offshore vivier fleet 1991-2006.

LPUE data was standardized using four different spatiotemporal model formulations with the Integrated Nested Laplace Approximation framework (INLA) and a common set of covariates which included a fixed year effect, an effort offset as number of pots, a smoother effect for soak time and a vessel random effect. Comparison of model predictive performance in terms of Root Mean Square Error (RMSE) (results not shown) suggested significant improvement in models that included spatial or spatial-temporal effects (Figure 1.20).

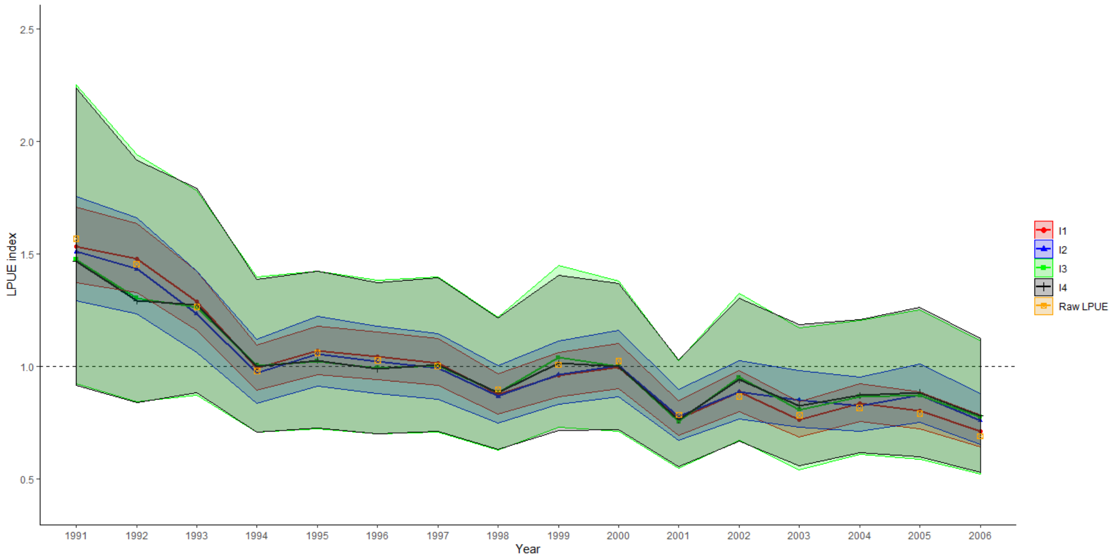


Figure 1.20. Standardized offshore LPUE time series using four different spatial-temporal model formulations in INLA. Nominal LPUE as squares included for comparison.

1.7 Brown crab (*Cancer pagurus*) in France

1.7.1 Landings, effort and catch data

Pots are the main gear used to catch brown crab in France (as it is for the French lobster fishery). The crab potter fleet follow the same regulations to access the resource as those pursuing the lobster fishery. The main regulations are licences schemes and limited number of pots per vessel. The fleet is composed by offshore potters, which perform trips between 7 to 10 days (in the centre of Western Channel and north of the Bay of Biscay) and coastal potters along the French coast. The gillnet fleet lands close to 20% of the total landings as a non-target species in the monkfish fishery. This scheme was in place for a long time until the last 2 years.

For a long time, the French brown crab landings were around 5000 to 6000 tonnes (Figure 1.21). Since 2016, the annual landings decreased around 500 tonnes reaching in 2022 less than 2000 tonnes. For each fleet in all areas, the trend is similar. Along the time series, the total effort has remained stable until 2019. As mentioned above, the access to the fishery is controlled and in the same period, there has been no change in the global fishing effort or in the spatial distribution of the fleet.

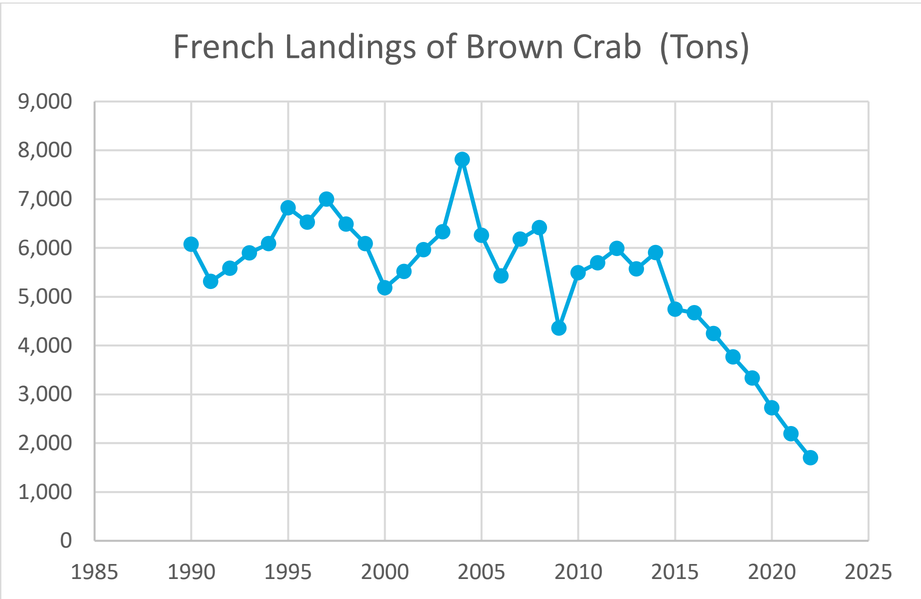


Figure 1.21. French brown crab landings (tonnes).

1.7.2 LPUE indicators of brown crab in France

From the data of the coastal potter fleet, the same approach as for the lobster (Section 1.21) was used to develop an index with a generalized linear model (GLM) from daily LPUEs. The trend from different areas (Eastern or Western Channel and Bay of Biscay) is quite clear with a decrease of the LPUE index in the last 7-8 years (Figure 1.22). In other areas, where limited vessel data are available to develop a LPUE index, the trend of single vessel is similar.

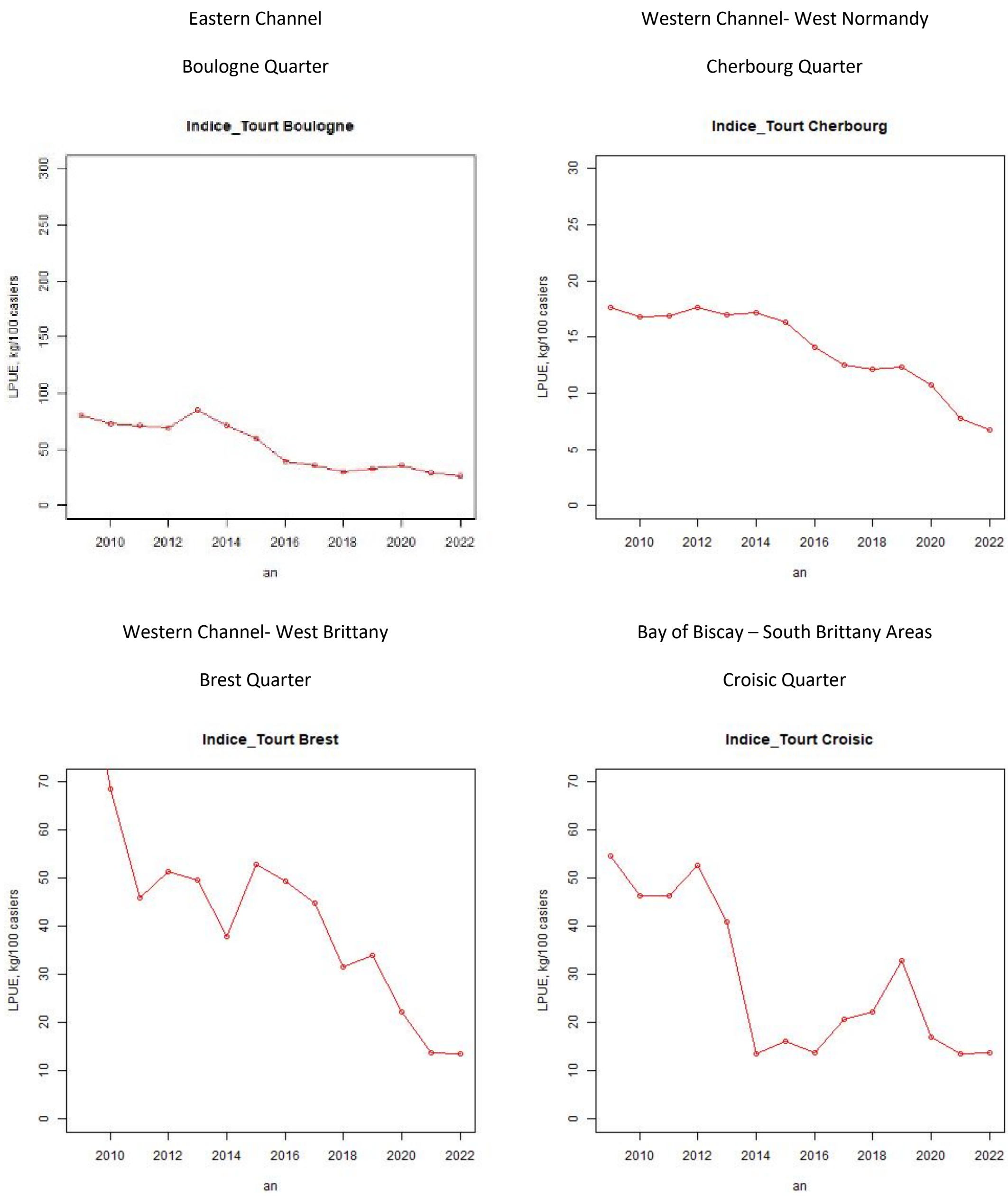


Figure 1.22. LPUE index trend in different areas from coastal vessels.

From the offshore potter fleet, the LPUE index trend seems to be equivalent even if the decrease seems to be more recent, from 2017. In order to have a more comprehensive understanding of the situation, the data to illustrate the recent trend are the raw data, daily LPUE of the offshore potters (Figure 1.23 and Figure 1.24). Since 2017, there is a clear decrease in the LPUE. In 2022, the values have stayed at a very low level all along the year without any peaks, as it was common during the autumn season. After many years with a stable LPUE index (although with some annual fluctuations but no trend), the reasons for the recent change is not presently clear.

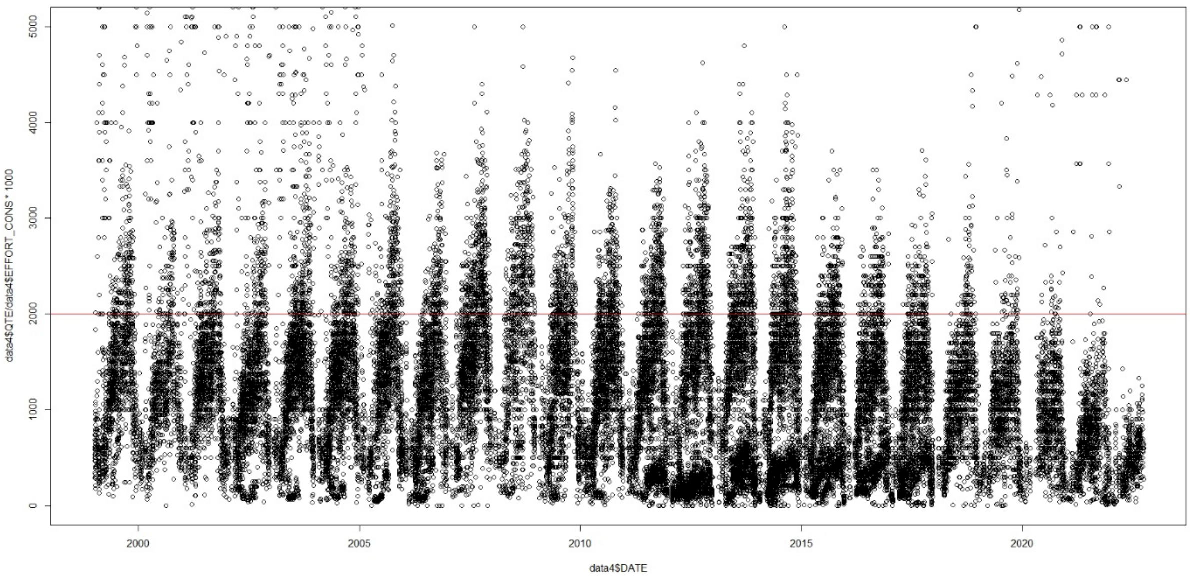


Figure 1.23 : Time series of daily LPUE from the offpotters in Western English Channel and Bay of Biscay.

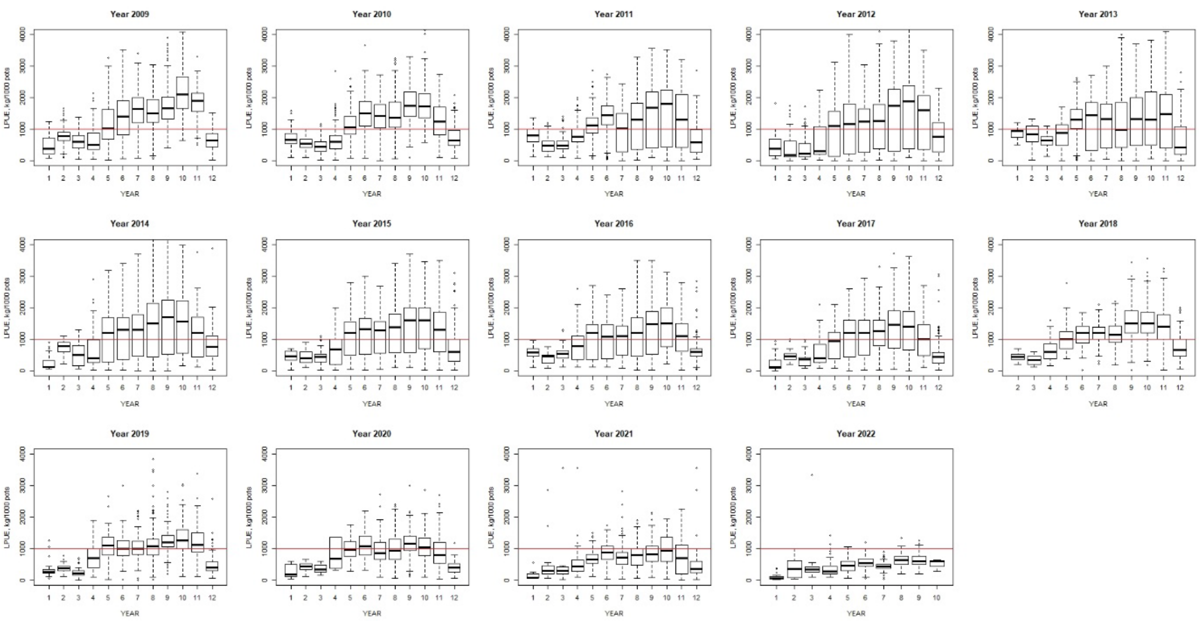


Figure 1.24 : Boxplot of the monthly LPUE from the offpotters in Western English Channel and Bay of Biscay.

Currently there is no data to explain the declining trend of the landings with an increase of the fishing effort or overexploitation given that the MLS of brown crab is higher than the size of maturity for both females and males. The decrease in landings started in coastal waters before reaching the offshore areas. This could be related with the brown crab ecology where juveniles and first adult stages are in coastal waters. A recruitment decrease could also be responsible for the current situation. A study will be carried out to explore two times series of larvae surveys where it may be possible to follow the trend of the last stage of larvae cycle (Megalopa). In addition, a study is starting to explore potential new diseases using molecular and histological approaches, but results are not yet available. For three years, collectors have been deployed to develop a recruitment index in three areas. Preliminary results show that very small crabs (less than 20 mm wide shell) have been caught but the data is not yet analysed.

The main impact of this situation of low catch rates is economic, with many vessels stopping their activity in 2022. Some have been sold in other countries while others have been converted to use gillnets. This social impact is important for fishermen and in addition, the experience and knowledge required to practice this type of fishing activity may not pass to future generations.

1.8 Brown crab (*Cancer pagurus*) in Norway

Brown crab is commercially exploited along most of the Norwegian coast from Skagerrak to Lofoten, with the main finishing area located in mid-Norway, in the statistical areas 06 and 07. Annual landings have been stable at approximately 5000 t after they peaked in 2007 (Figure 1.25). The fishing fleet is dominated by vessels below 11m with limited reporting duties, severely limiting data availability to sales notes from landings as the only consistently reported information from the fishery. Until 2022, logbook data was reported only from a few larger (> 15m) vessels and is, thus, not representative. An expansion of electronic logbook requirements to smaller boat is planned but has partially stalled due to implementation challenges. Currently, the fishery is open-access and largely unregulated except for a minimum landing size at 11 and 13 cm south and north of Rogaland, respectively.

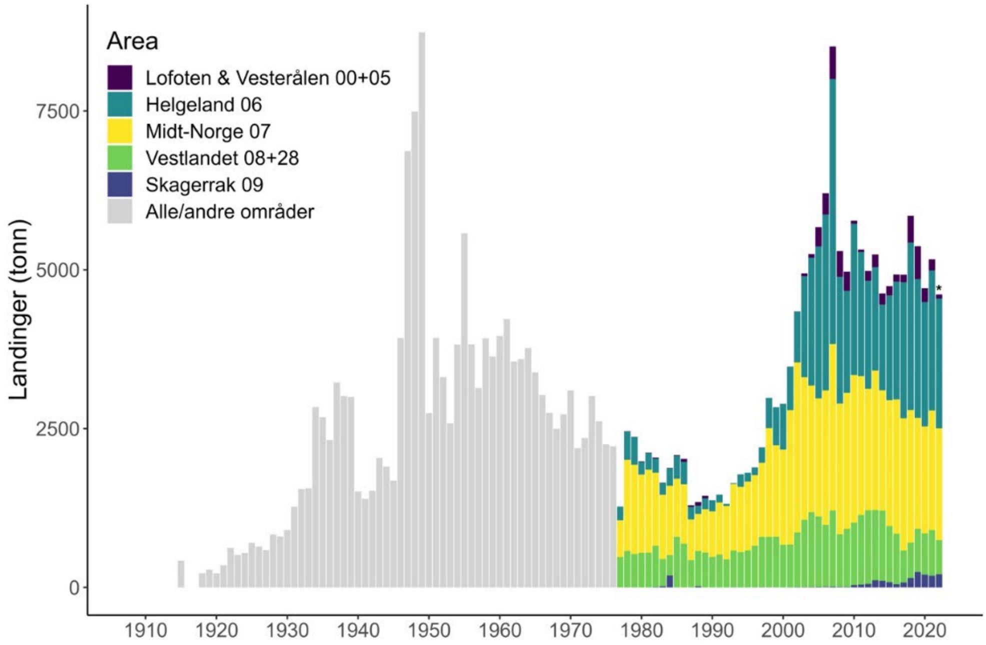


Figure 1.25. Total Norwegian landings of Cancer pagurus per region from 2005 to November 2022, based on landing slips from commercial fishers.

1.8.1 Reference fishery network and potting survey

To compensate for the lack of logbook data, a network of crab fishers was established in 2001. Reference fishers are each provided with four standardized pots, and they report the entire catch of these pots including carapace width and sex of all crabs caught, and whether they are landed or discarded. In addition, the statistical location (grid cell), fishing depth and soaking time of the crab pots are registered. To increase the participation rate and data quality, the reporting has been reduced to a biannual cycle since 2015. Despite the limited resolution, these data are the only available data source for catch and effort data as well as length frequencies of brown crab in Norway, as effort or biological data are not explicitly reported in sales notes and there are currently no other data collection programs.

In August 2021, a fishery-independent crab stock survey was conducted as a collaboration between the Institute of Marine Research (IMR) and the Fisheries Directorate of Norway (Marcussen *et al.*, 2022a). Parallel to IMR's coastal gillnet and fyke net survey, some of the fishing areas with the highest commercial landings were sampled. There were 79 stations sampled with trap links consisting of the same pots used by the reference fishers. The intention of this study was to cross-validate the reference data. The survey successfully validated the commercial fishers, as the catch rates (crabs per pot) in the independent survey corresponded to catch rates observed in the reference fishers in the same area during the same time. Based on this analysis, it can be assumed that the data reported by the reference fishery is representative of the stock density in a specific area. A similar investigation will be conducted on a survey in 2023 in the region of West-Norway.

1.8.2 Stock status

Overall, available data indicates a stable, likely good state of the Norwegian crab stock on a national scale and sustainable fishing pressure. Using the reference fishery catch data and the landing slips from commercial fishers, standardized CPUE and LPUE indices were estimated (Figure 1.26). The trends showed no significant changes through the time series on a national scale. However, the crab population is distributed over more than ten degrees of latitude, and regional stock variation may occur. Estimation of LPUE indices that include regional trends (modelled as autocorrelated random effects of areas over time) based on dividing the stock into five management units, indicates differences in the development and stock units over time (Figure 1.27). The northernmost region, Lofoten and Vesterålen, indicates large variations and an increase since 2015, whereas the two intermediate regions, Helgeland and Midt-Norge indicate stable trends (Figure 1.28). These two regions are also the most important commercial fishing regions, with stable catches over the last 20 years. Vestlandet experienced a rapid decline from a high LPUE after 2015. The southernmost region, Skagerrak, has no major changes throughout the time series and large uncertainties due to low commercial fishing activity. Overall, it remains unclear whether the indices are representative of the changes in the stock because of the coarse resolution of landings data that constrains standardization. This is particularly problematic for areas with limited data due to low or very variable fishing activity mostly caused by economic drivers, as found in the northern- and southernmost regions.

Whereas the reference data suffer from substantial variation causing large uncertainties, partially because of low participation rates in most regions, the landing data includes all landings of the commercial fishing fleet and covers therefore consistently all areas in Norway. This allowed for LPUE standardization for area-specific trends instead of one index for the whole of Norway. Because landings data does not include explicit effort data, landings per boat trips have been used as a proxy for LPUE, which has been shown to provide representative trends for the similar Norwegian *Nephrops* creel fishery when properly standardized (Zimmermann *et al.*, 2022). Because vessel- and haul-specific differences in effort and catchability are relatively constant in a pot fishery with little variation in terms of number and types of pots, fishing location, etc. among fishing trips, it can be assumed that vessel random effects absorb most of the differences in catch rates between vessels. This was confirmed for brown crab where both the area effects as well as the LPUE index correspond well to the results from the CPUE standardization (Figure 1.26).

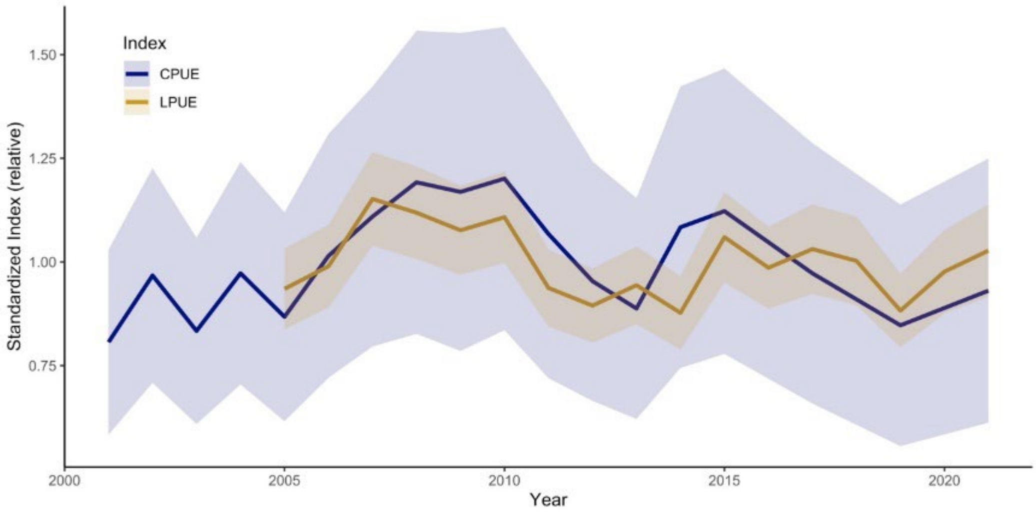


Figure 1.26. Standardized CPUE and LPUE indices on a national scale, they are based on reference fishery and landings slips, respectively. Areas included in the two indices is statistical area 06, 07, and 08.

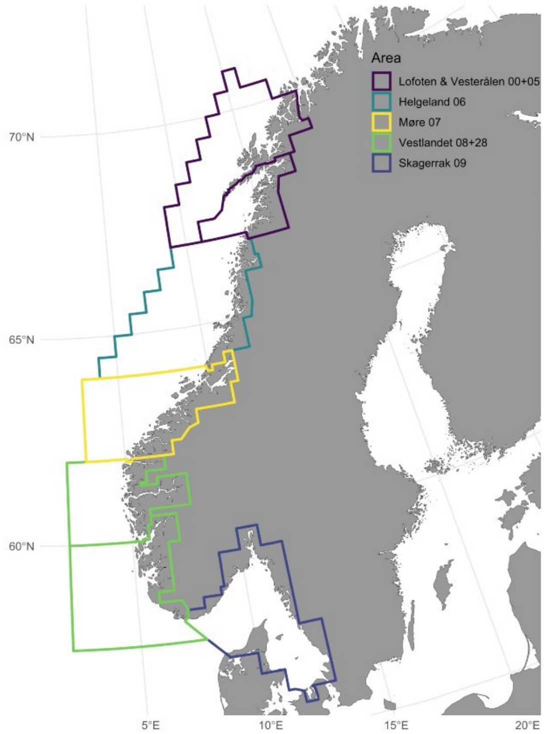


Figure 1.27. Overview of the predefined management units in Norway.

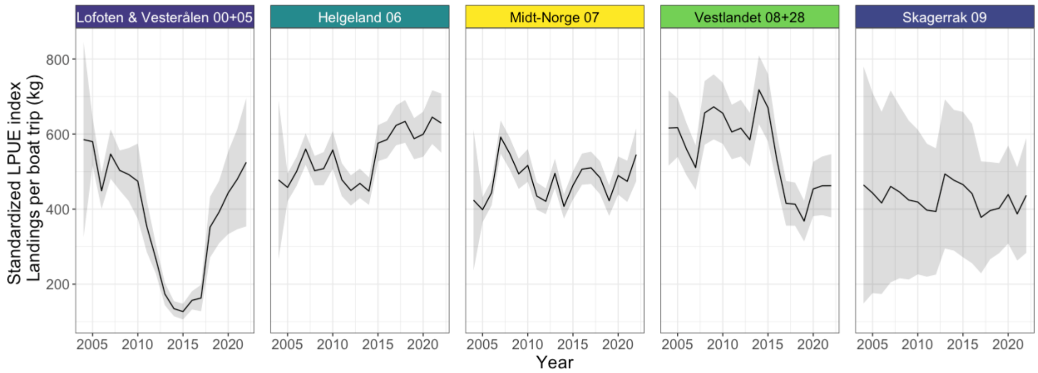


Figure 1.28. Standardized LPUE index on a regional scale based on landings slips, from all major statistical areas present in the Norwegian crab fishery.

1.8.3 Future research

The status report in 2022 (Marcussen *et al.*, 2022b) concluded that the brown crab fishery was in general stable in the three northern most regions, while in Vestlandet the decline after 2015, smaller crabs, and low MLS the evaluation of additional management measures based on a precautionary approach was advised. This includes a re-evaluation of the lower MLS in the southern regions of Norway. As there are large uncertainties related to the estimates in several regions and notably Vestlandet, fishery-independent data should be collected in these areas to cross-validate the available commercial data. In 2023, a survey with this objective will be conducted in the Vestlandet region. Furthermore, a survey in the currently not monitored region of Troms north of Vesterålen will aim to assess the distribution and stock density in an area where brown crab has been expanding in recent years, but information is severely limited because of little to no commercial fishing. Results are expected to give insight on the northward expansion of the crab, will potentially provide new fishing grounds, and a baseline study on a largely unfished stock will be essential for the monitoring and management of a potential future fishery in this region. Additional research will focus on improving or adjusting current assessment methods to the specific data requirements, fishing selectivity, etc. to determine suitable candidate stock assessment models (see Section 0).

1.9 Brown crab (*Cancer pagurus*) in Sweden

The brown crab occurs in Sweden on the west coast in the Kattegat, Skagerrak and north part of the Öresund. The brown crab is an important species that is fished both for household needs and as an important commercial fishery. They are mainly fished with crab tins (74% in 2021) and nets both in the Skagerrak and Kattegat (Figure 1.29) but are also obtained as bycatch from bottom trawling. Crab tins used in water shallower than 30 meters must have at least one circular escape opening with a minimum diameter of 75 millimetres located in the lower edge of the outer wall of each compartment, to allow small catch to exit the gear (HaV, 2015). From January 2023, crab cages must be fitted with escape holes of 15 cm, closed with a cotton yarn, to prevent ghost fishing. The number of tins is unlimited for commercial fishermen but limited up to six per recreational fisherman and a total of 180 meters of nets may be used by recreational fishermen. When fishing with tines, no more than 1% of the weight of the total brown crab catch may consist of detached claws (HaV, 2018).

Figure 1.29. Brown crab fishing areas in the Swedish coast.

1.9.1 Landings

Most of the brown crab landings in Sweden are taken during the summer and autumn, quarters three and four. Historically, there was a clearly defined catching season from July to November (Figure 1.30). In recent years, there has been a more even distribution throughout the year, with a peak season in the fourth quarter. Swedish landings made up approximately 48%of the reported professional total landings in the area in 2021, while Norway accounted for 30% and Denmark for 22% of the remaining catches (Figure 1.31). The catches take place geographically along the coast and around the island of Læsø (Figure 1.32). Official commercial landings of crab in the Skagerrak and Kattegat have increased from around 100 tonnes in the 1970s to the 1990s to around 600 tonnes in recent years (Figure 1.31). The reason for this increase is unknown.

The total catch of crab is significantly greater than the official landings due to unregistered bycatches, dumping and catches in recreational fishing. The natural mortality has probably decreased in recent years due to a reduced presence of predators (primarily cod).

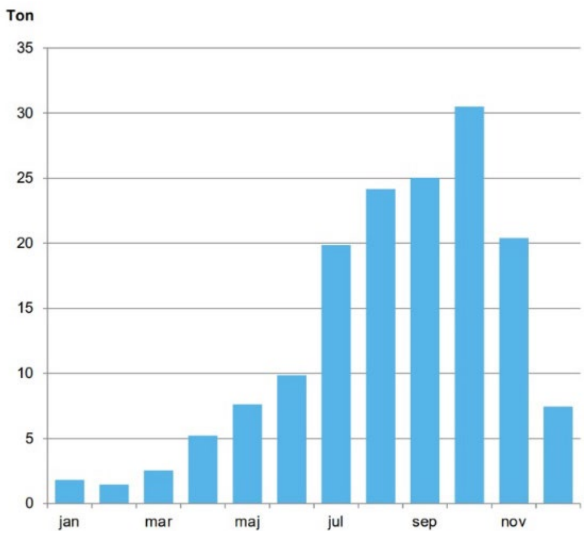


Figure 1.30. Landings (tonnes) of brown crab by the Swedish commercial fishery, distributed by month for 1990–2021.

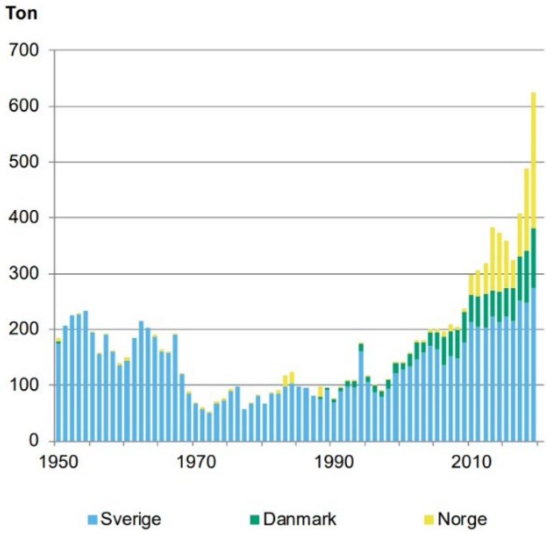


Figure 1.31. Commercial landings of brown crab, 1950 - 2021 for Sweden, Denmark and Norway.

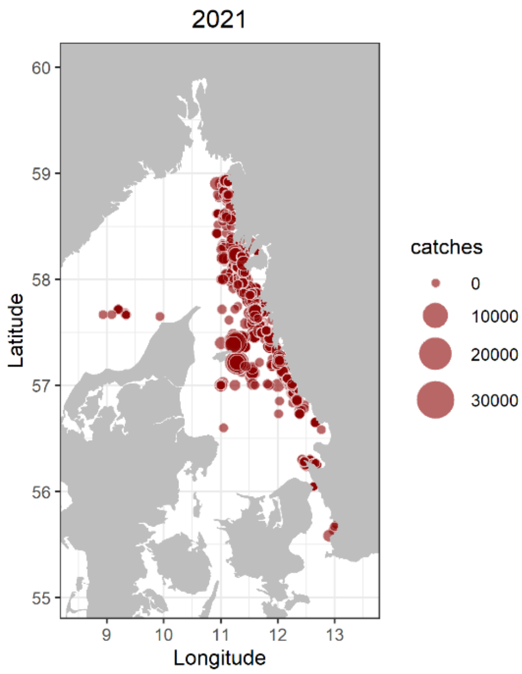


Figure 1.32. Spatial distribution of crab catches along the Swedish west coast, 2021.

1.9.2 Stock status and structure

There are currently no surveys of the status of the crab stock, but logbook data and interviews with fishermen indicate that the stock is at a relatively high level. Catch per unit effort (kg crab per tin) is available from the professional fishing logbook in the last fourteen years (Figure 1.33). Only 19%of the Swedish logbook landings are made up of daily logbook keepers, which are the data that has been used in calculations to estimate kg of crab per tin. If this measure is used as an indicator for fishing mortality, crab fishing seems to be on a long-term stable and sustainable level.

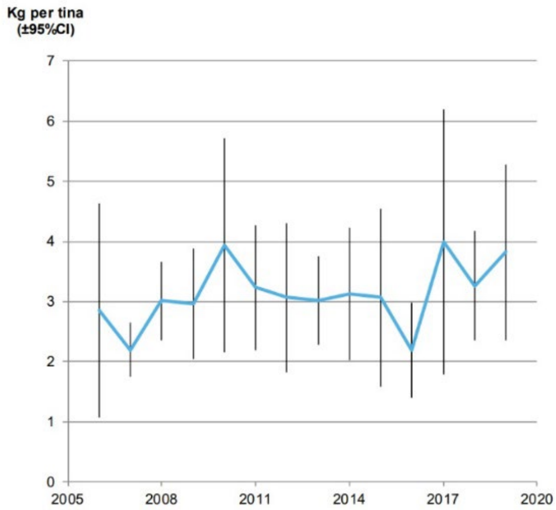


Figure 1.33. Catch per effort (kg per crab tin) in the Swedish commercial fishery during the high season (June–November) 2006–2021. Error bars are 95 percent confidence intervals.

1.10 Spider crab (*Maja brachydactyla*) in Jersey

1.10.1 The spider crab fishery in Jersey

During the last three-year WGCRAB cycle, Jersey has continued to monitor its spider crab stocks through both landings and effort data, and independent surveys. This report summarises the key information pertaining to the spider crab fishery and provides an update on landings trends. In Jersey, there is no TAC or quota for spider crab. Pot fishing in Jersey is currently regulated using a Minimum Landing Size (MLS) of 87 mm carapace width (no max landing size), a pot cap (typically 1000 pots per vessel), and a recreational daily bag limit of 10 spider crabs per fisher and 50 per vessel. VMS is available for vessels >12 m in length; vessels under <12 m will be required to have iVMS by January 2024.

Jersey has a commercial fishing fleet consisting of 135 vessels with most being < 10m in length. Jersey's fleet uses a range of fishing methods with potting being the dominant metier used across the island's commercial fleet. This is to be expected given the major role that crab and lobster contributes to the fishery. While spider crab can be caught by nets, they are targeted primarily from the static potting fleet, which constitutes 90% of the Jersey fishing fleet. Although a variety of pot types are used, parlour pots account for nearly 90% of total fishing effort. Parlour pots are an efficient method of capturing crab and lobster as once an individual enters the second holding chamber it is not able to exit again, and it is for this reason that parlour pots are excluded from two areas of offshore reef that are key fishing grounds for crab and lobster. Two No Parlour Pot Zones (NPPZs) are currently in place, one at Les Minquiers to the south of Jersey that was established in 2007 and another to the north east of Jersey at Les Ecrehous which was established in 2017 (Figure 1.9).

The spider crab forms a key part of Jersey's commercial fishing industry. Since at least the late nineteenth century it has been targeted by Jersey vessels. Most spider crabs landed in Jersey, around 90%, are exported to Europe via France either as direct landings from Jersey fishing vessels or via the islands fish merchants. Jersey waters are also fished by vessels from Normandy and Brittany and were, until 2021, subject to joint management through the Bay of Granville Agreement (GBA). Data provided by Ifremer suggests that the spider crab fishery is exploited to a lesser extent by Jersey vessels compared to French vessels. The spider crabs caught in the Bay of Granville area equates to over half of all European spider crab landings, and the majority of these spider crabs are taken by French vessels operating to the south and west of the island using benthic tangle nets (Marine Resources, 2019).

Prior to the decline in landings in 2020, as a result of Brexit and Covid, spider crab landings had been increasing since 2013.

1.10.2 Catch data

Spider crab catch increased from 81,041 kg in 2013 to 307,333 kg in 2019 (Figure 1.10). In 2020, landings dropped to 277,870 kg and did not increase significantly in 2021, but still remain higher than landings prior to 2017. There are various ongoing monitoring programs being conducted by the Marine Resources team to better understand long-term changes in spider crab stocks. These datasets include:

- Commercial logbook data (2007-Present)
- Annual spring potting studies (2004-Present)
- Autumn potting studies in Marine Protected Areas (2018-2020)

The commercial fleet have submitted daily effort and catch statistics since 2007 in the form of logbooks. These logbooks are received quarterly and are mandatory for all licenced Jersey fishing vessels. Weights are in kg and are recorded for one of six zones. Effort is recorded in pot lifts and the type of pot must be recorded e.g. inkwell, parlour or D Pot. Marine Resources holds catch statistics going back to the 1960s but both the makeup of the fleet, its fishing grounds and the quality of the data have varied over the years so consistent records on which management decisions can be based are considered to start from 2007.

Landings per Unit Effort (LPUE) for spider crab has steadily increased since 2013 and was highest in 2019 at 17.4 kg per 100 pots (Figure 1.34). The overall effort in terms of pot lifts peaked in 2017 and has since declined, with the lowest number of pot lifts recorded in 2021 at around 1 million pot lifts. The use of all types of pot has been decreasing since 2017 which is driven by the decline in use of parlour pots (Figure 1.35).

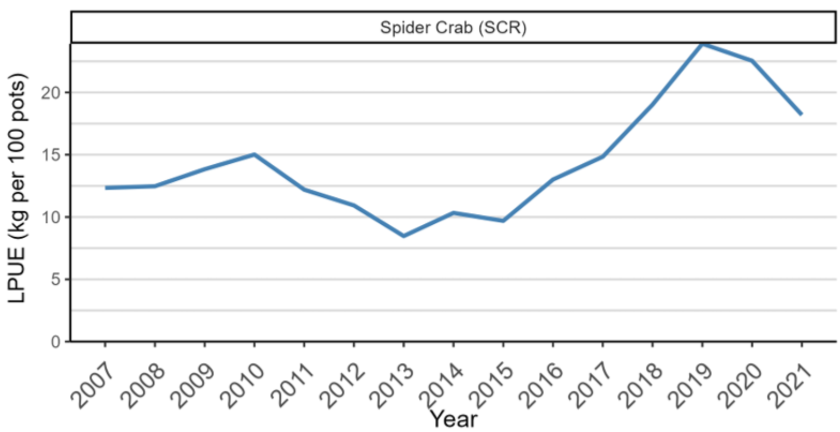


Figure 1.34. LPUE (kg per 1000 pots) for spider crab between the years 2007 and 2021.

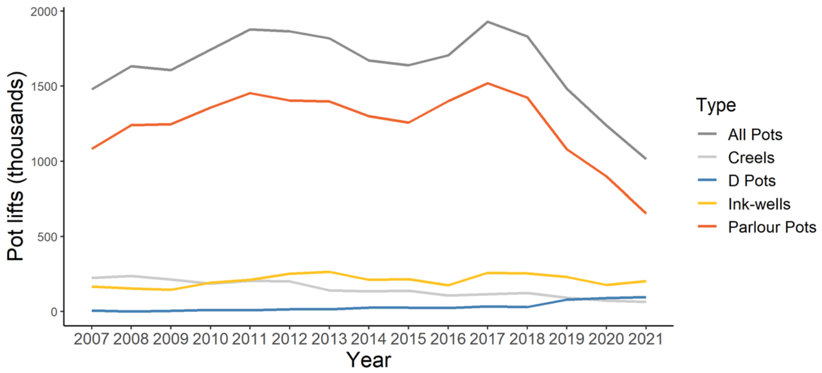


Figure 1.35. Number of pot lifts for different pot types used in the Jersey commercial lobster fishery.

1.10.3 Annual potting surveys

Since 2004, Jersey has conducted an annual sampling program using adapted parlour pots to capture and record crustacean abundances each year, with spider crab being included in measurements since 2008. Thirty pots are fished five times across May and June each year in three locations considered representative of the fishery (Figure 1.13). The pots are of the parlour design and do not have escape gaps. The pot mesh is also smaller than current parlour pots to capture and record juvenile crustaceans. Following a 48-hour soak, the pots are recovered and all shellfish are measured. In respect of spider crab, the following measurements are taken: carapace length, carapace width, carapace depth, sex, berried status, damage and disease.

The mean number of spider crabs caught per pot have been steadily increasing over time. The proportion of sized (>MLS) to undersized (<MLS) individuals varied until 2018 where there were over twice as many sized (>MLS) as undersized (<MLS) caught, as was also the case in following years (Figure 1.36). Figure 1.37 shows the frequency of spider crab both above and below MLS are increasing. The distribution of size ranges over time have been variable but in recent years have become more truncated.

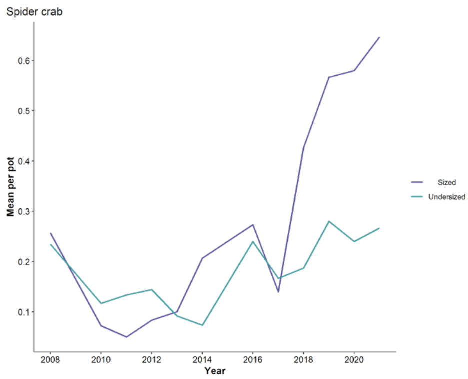


Figure 1.36. The number of spider crab individuals caught per pot between 2008 and 2021.

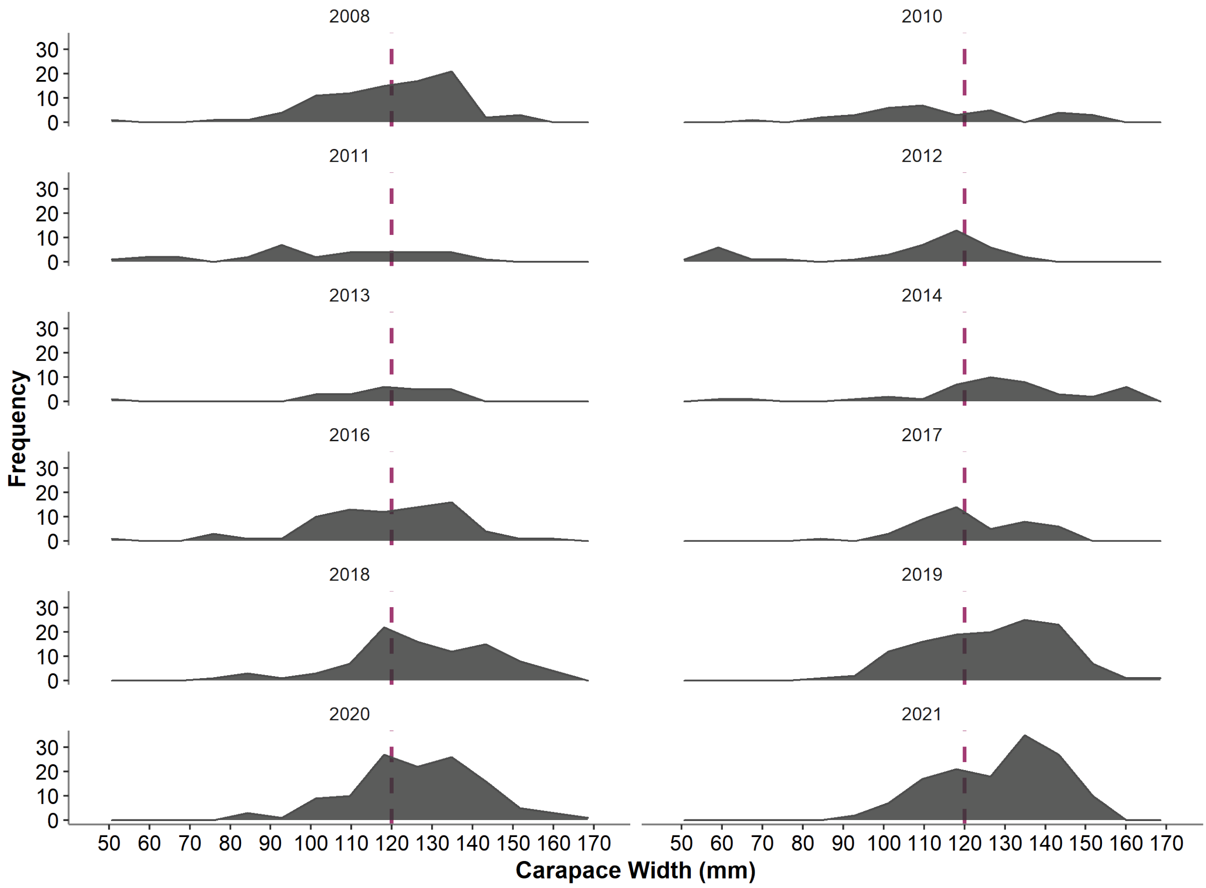


Figure 1.37. Size distribution of spider crabs caught in the annual trials between 2008 and 2021.

From 2018 an additional potting survey was introduced (during autumn) at Les Écréhous and Les Minquiers as part of a PhD project to assess the commercial crustacean populations at the offshore reefs. Pots were set across three separate management areas: Marine Protected Areas (where mobile gear is excluded); No Parlour Pot Zones, and Open fishing areas. The results showed spider crab abundance varied between locations, treatments and years. The full study is available on request.

1.10.4 Dredge surveys

In 2021 and 2022, dredge surveys have been undertaken in Jersey waters as part of a scallop stock assessment. Spider crab are also prevalent on the same ground as scallop and it is possible to use this information to assess spider crab density in the survey areas. A baseline survey was carried out across March 2021, and a second survey was carried out in September 2022. Two fisheries officers worked alongside two crew to survey 42 sites across 6 reporting zones in both years. The Starboard side bar was fitted with standard commercial gear (three bags with 85mm bellies and 8 tooth swords), while the port side was fitted with research dredges (three bags with 50mm 'queenie bellies' and 13 tooted swords). It was possible to estimate the 'swept' area of the dredge by multiplying the combined width of the dredge bags (in metres) by the total length of the tow (also in metres). This was then used to calculate the number of spider crabs per m^2 of seabed. Results are presented per reporting area. Size frequencies were investigated using kernel density plots.

There were more spider crabs caught in 2022 compared to 2021 (Figure 1.38), and while there are reports that spider crab abundances have been increasing in recent years, the difference observed here is mostly a reflection of the seasons sampled. In 2021, slightly more spider crabs were caught per m^2 in the 50 mm ring size dredge compared to the 85 mm, except in areas 26E7BG and 27E7BG where the catch was equal. The opposite trend was observed in 2022, with more spider crabs being caught in the 85 mm ring size at all locations. The main difference in ring size predicted was that there would be lower catch in the smaller ring size due to the bags filling up quicker with debris, which holds true in 2022, but not in 2021. The reason for this may be explained by Figure 1.39, which shows the size distributions.

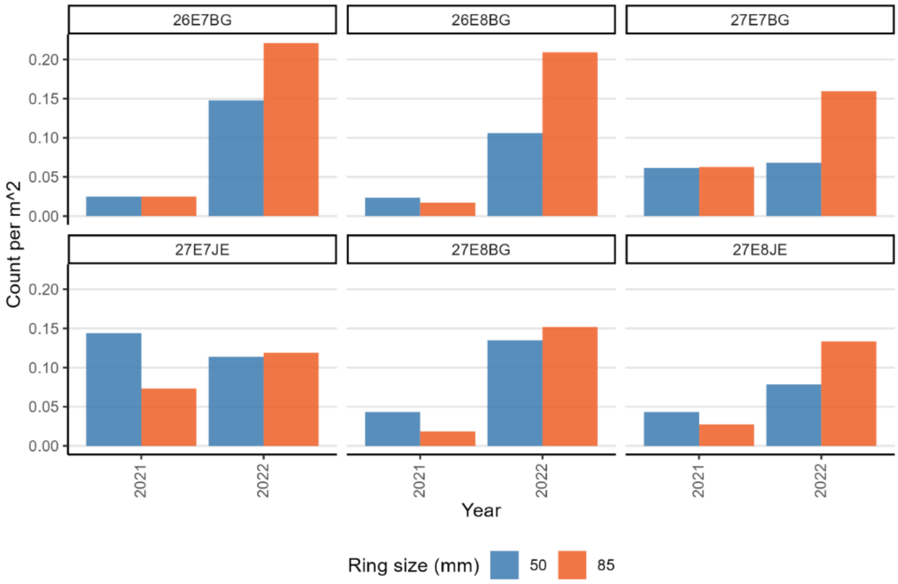


Figure 1.38. The number of spider crabs caught per m^2 in each dredge ring size (50 and 85 mm) in 2021 (spring) and 2022 (autumn) shown for each area.

Ring size had an effect on the size distribution of spider crabs. In 2021, there was a greater proportion of smaller individuals caught, with more retained in the 50 mm ring size compared to the 85 mm. This may explain why there was a greater number of spider crabs per m^2 surveyed in 2021, as there were greater numbers of smaller spider crab on the ground that may have fallen through the 85 mm rings. This size selectively was also observed in 2022, where the smaller individuals were only observed in the 50 mm ring size. However, this difference was less marked, and may be related to a greater number of larger individuals on the seafloor. In 2021, there were few individuals caught that were above MLS, whereas approximately half were above MLS in 2022. This correlates well with the timing of adult spider crab migration into shallower areas (such as those surveyed for this study) over the summer, where they typically remain until the later months of autumn when they migrate back into deeper 'over-winter' areas outside of Jersey waters. The only exception in 2022 was in 27E7JE where there were less individuals caught above MLS compared to below MLS.

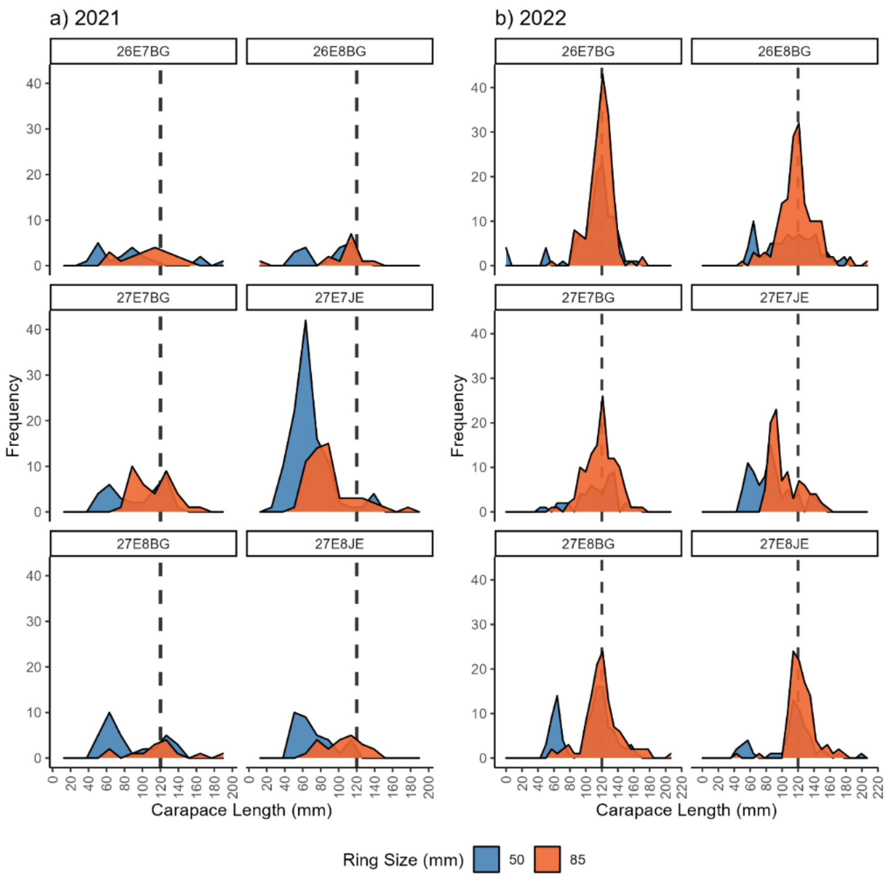


Figure 1.39. The frequency of spider crab individuals caught in each size class of carapace length (mm) in each dredge ring size (50 and 85 mm) per rectangle area. The dashed vertical line indicates the Minimum Landing Size (MLS).

1.11 Spider crab (*Maja brachydactyla*) in France

The spider crab landings in France were close to 8000 tonnes in 2020 and 2021 but decreased to under 7000 tonnes in 2022. The main fishing gear were gillnets (80%) in the Normano-Breton bay. The remaining 20% were landed along the coast from potters and trawlers. Presently it is not possible to estimate a robust abundance index from the different fleets due to (1) difficulties estimating effort for the gillnet fleet because the size of nets and the soak time (which is variable) are not declared; (2) for all fleets, there is evidence of high grading. Therefore, the LPUE can be only used to reflect the global trend. Despite a robust abundance index not being available, observations of the fishermen and other stakeholders on the shore confirm the high abundance of the spider crab in the last 3 -4 years. This results in spider crab being currently more widely distributed in the coast of France in areas where they were not observed before (or were only recorded seasonally).

1.12 Snow crab (*Chionoecetes opilio*) in Canada

Atlantic Canadian snow crab are managed by four separate administrative regions of Fisheries and Oceans Canada (DFO), with the largest biomasses occurring in the Newfoundland & Labrador (NL) and southern Gulf of St. Lawrence (sGSL) regions. These regions encompass the Northwest Atlantic Fisheries Organization zones 2HJ, 3K, 3LNO, 3Ps, 4R3Pn, and 4T. The two dominant regions of NL and sGSL have had exploitable biomass indices opposing one another for much of the past three decades but in recent years both regions have shown coincidental increases in exploitable biomass (Figure 1.40 and Figure 1.41). This has resulted in 2022 landings approaching historical highs, with about 94,000t of removals in 2022 (Figure 1.42). Short-term recruitment prospects are favorable for continued high fisheries productivity and where available Precautionary Approach frameworks indicate the resource is healthy. The Atlantic Canadian zone has experienced warming since the mid-1990s that is affecting all portions of the water column, which could be a concern for long-term productivity of the snow crab resource.

Below are landings for the entire stock, NL exploitable biomass [2HJ3KLNOP4r; note green and brown are recruitment and residual biomass from trawl surveys while blue is trap survey estimates for recruitment and residual biomass combined; dashed lines are annual estimates and solid lines are 2-year moving averages], and sGSL exploitable biomass [4T; observed values are from trawl survey and predicted values from stage-based model].

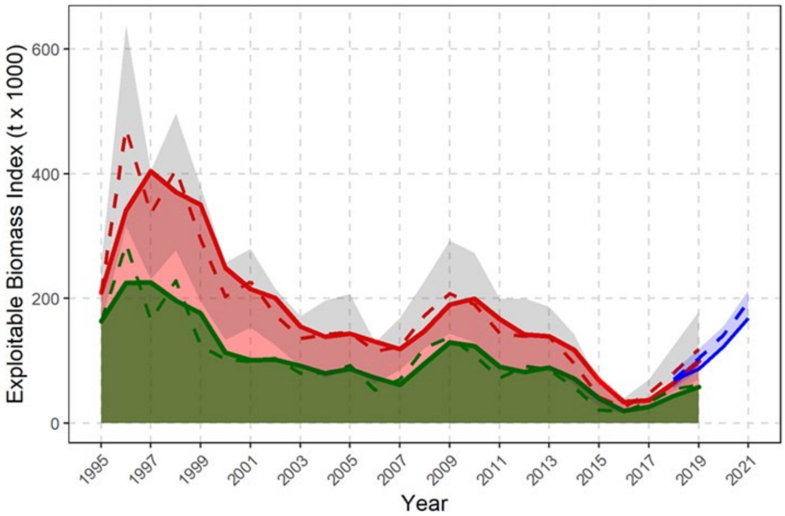


Figure 1.40. Newfoundland & Labrador exploitable biomass. Green and brown are recruitment and residual biomass from trawl surveys while blue is trap survey estimates for recruitment and residual biomass combined; dashed lines are annual estimates and solid lines are 2-year moving averages.

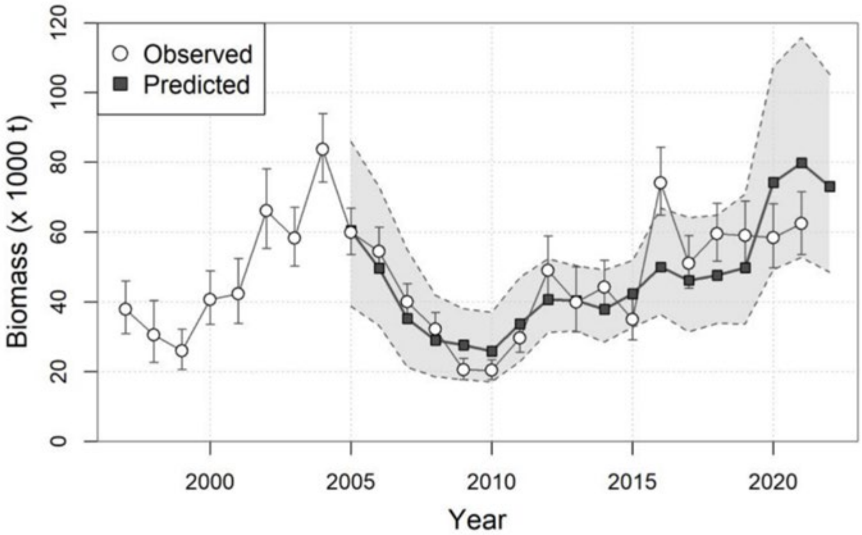


Figure 1.41. Southern Gulf of St. Lawrence exploitable biomass. Observed values are from trawl survey and predicted values from stage-based model.

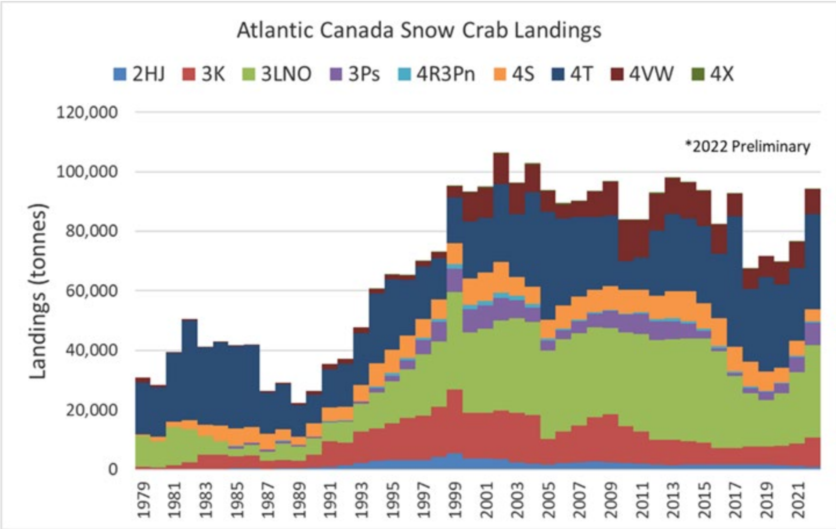


Figure 1.42. Snow crab landings in Canada.

1.13 Snow crab (*Chionoecetes opilio*) in Norway

The snow crab (*Chionoecetes opilio*) stock has since 1996 increased rapidly both in distribution and abundance in the Barents Sea. It is now expected that the snow crab inhabits large parts of the Russian exclusive economic zone, the entire Loophole (international waters in the central Barents Sea) and increasing parts of the Svalbard Fishery Protection Zone (Svalbard FPZ).

The fishery for snow crab commenced in 2012, and the main fishing area is in the central part of the Barents Sea. The fishery is an offshore fishery, and the fleet consists of large vessels between 40 and 70m with on-board processing. The vessels probably operate between 1000 and 2000 pots every day. Snow crab in the Barents Sea fishery is exclusively harvested using conical pots deployed in strings connected to longline. The minimum legal size for male snow crab in the Barents Sea has been 100mm carapace width (CW). From November 2020, the legal size has been reduced to 95 mm CW. All undersized snow crabs and females must be returned to the sea. The management regulations in the Svalbard Fisheries Protection Zone and Norwegian EEZ are as follows: minimum legal size of 95 mm CW; maximum of 9,000 pots (reduced from 12,000) deployed per vessel; maximum soak time for pots of three weeks; mandatory use of pot gear only; the fishery is closed and all pots must be removed from the seabed from June to October; and a maximum of 20% post moult crab caught (Norwegian Fisheries Directorate (www.fiskeridir.no), 2018).

The snow crab fishery in Norway has the following management goals: "*the snow crab will be managed with the goal of sustainable harvesting based on the knowledge on how the species affect each other in the ecosystem. This will be achieved by balancing two sub goals; maximizing long-term catch yield and minimize the risk of unwanted ecosystem effects.*"

A small fishery was initiated in 2012, and the total landings from the Barents Sea peaked in 2016 with a total of 16000 tonnes, all landed in Norwegian harbours. In the beginning, Norwegian, EU vessels and Russian vessels fished in the central parts of the Barents Sea. From 2017 new regulations caused that only Norwegian vessels can fish on the Norwegian continental shelf and Russian fishing vessels fish on their shelf. Both Norwegian and Russian governments introduced a TAC from 2017. In 2022, a total of 23300 tonnes of snow crab were landed by the Norwegian and Russian fleets from the Barents Sea (Figure 1.43 and Figure 1.44).

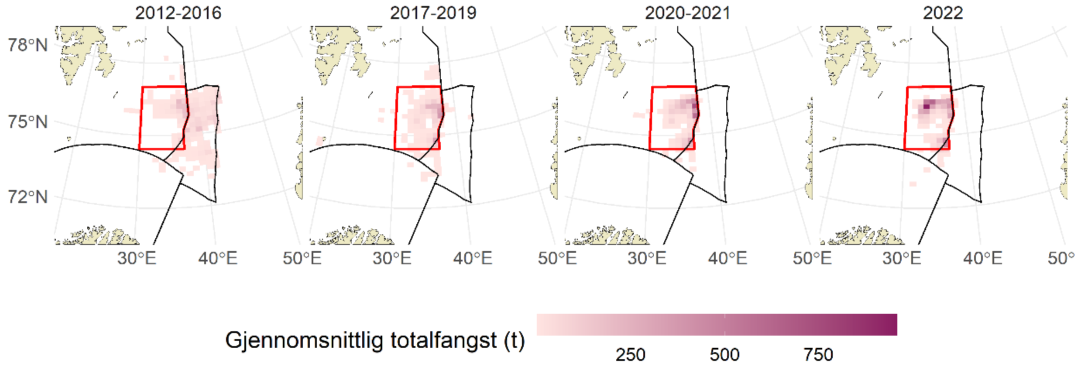


Figure 1.43. Showing fishery activity from Norwegian vessels in the unregulated period 2012 – 2016, and the regulated period divided in 2017-2019, 2020-2021 and for 2022.

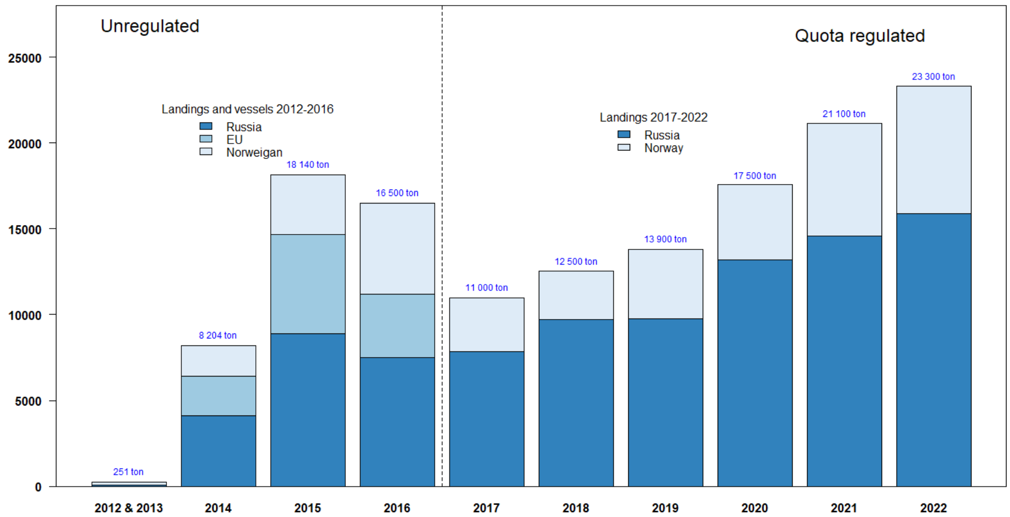


Figure 1.44. Overview of total landings of snow crab from the Barents Sea in the period 2012 to 2016 when the fishery was unregulated, and landings between 2017 and 2022 for the quota regulated period.

1.14 Red king crab (*Paralithodes camtschaticus*) in Norway

The harvest of the red king crab (*Paralithodes camtschaticus*) in northern Norway has a fishery history since 1994. Present management regime was established in 2008 and have since then been primarily a male-only fishery, but there is also an additional small quota on female crabs. In the dual management regime there are two goals, one is to maintain a long-term commercial harvest in a limited geographical area with total allowable catch (TAC) and restricted participation (East Finnmark). The other goal is to limit further spread of the red king crab and minimize crab abundance outside the commercial area, west of North Cape. There is also a profitable fishery going on in West Finnmark, and it is used as a tool to fulfil the goal of reducing the further spreading of the red king crab.

The Institute of Marine Research in Norway carries out two annual cruises in the quota regulated area to assess the stock and advise on harvest. In addition, a trap survey is performed in coastal areas west of the quota regulated area to monitor the spread of the crab. After ten years of surveillance, it seems that the free fishery can limit the rate of spread and keep the stock at low levels in areas where the crab is established.

During the last eight years, the landings of the red king crab in the quota regulated area have been stable (Figure 1.45). About 800 fishermen can participate in the fishery and the value of the landings has reached high values (around 800 million Norwegian kroner). The landings in West Finnmark have varied more due to the variance in effort, nevertheless the first hand value of the landings has varied, and in average about 300 boats participate.

Data collected on the red king crab surveys are analysed using a compound production model. This model provides alternative harvest options with affiliated risk analysis. The quota has been stable and varied between 1500 to 2000 tonnes the last six years.

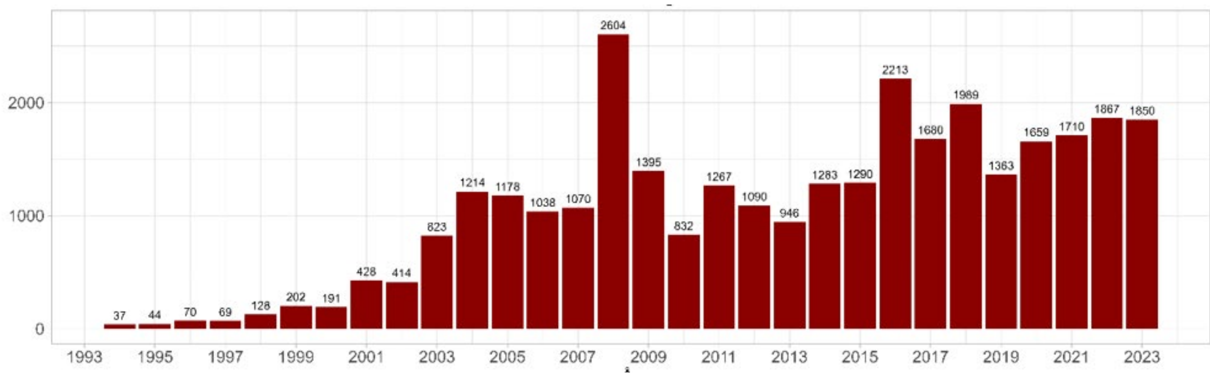


Figure 1.45. Total landings of red king crab in the period 1994 to 2023.

1.15 European lobster (*Homarus gammarus*) in Scotland

The European lobster is found all around the coast of Scotland typically in shallow waters below 60 m. The European lobster is a valuable species for which seasonal prices can be as high as £20 per kg at first sale. For management purposes, the lobster assessment units around Scotland are the same as those of brown crab (Figure 1.1). Total Scottish landings of lobster fluctuated between 1,000 and 1,200 tonnes from 2012 to 2021 (Table 1.2). The total tonnage of lobster landed in Scotland has consistently been much lower than that of crabs. However, reported lobster landings have increased substantially over the last years. Historically the majority of landings of lobster in Scotland have been from the Hebrides, Orkney and South Minch, with the South East and East Coast areas becoming increasingly important in more recent years (Figure 1.46). Landings from these areas accounted for around 86% of the total in 2021. Small quantities of lobster were landed from grounds outside the assessment areas, including ICES rectangles to the west of South Minch Hebrides and Sule, to the south of Clyde and just outside the Orkney, South East and East Coast areas. The majority of lobsters fished in Scottish waters are landed in the third and fourth quarters of the year. Stock assessments have been carried out for lobster since the 1990's. The latest assessment results for lobster in Scotland are presented in Section 2.7.

Table 1.2 .Annual Lobster landings (tonnes) into Scotland by creel fishery assessment unit from 2012-2021.

Assessment unit	Year									
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Clyde	19	20	41	31	35	38	29	26	25	34
East Coast	265	215	226	228	255	348	355	282	245	244
Hebrides	139	97	149	115	127	133	171	160	174	172
Mallaig	13	1	1	1	1	1	2	3	4	5
North Coast	10	10	11	13	15	16	11	12	10	11
Orkney	156	117	164	114	117	114	98	109	112	118
Papa	6	6	8	3	3	3	1	2	2	2
Shetland	37	36	40	41	53	56	39	42	37	23
South East	334	388	409	349	367	326	327	339	274	331
South Minch	90	78	106	83	102	112	112	124	132	124
Sule	2	1	1	1	0	1	1	1	0	0
Ullapool	12	15	17	14	14	18	21	25	19	12
Outside Assess. Units	50	42	36	50	62	48	53	63	55	69
Total	**1132**	**1026**	**1208**	**1042**	**1151**	**1214**	**1220**	**1190**	**1089**	**1145**

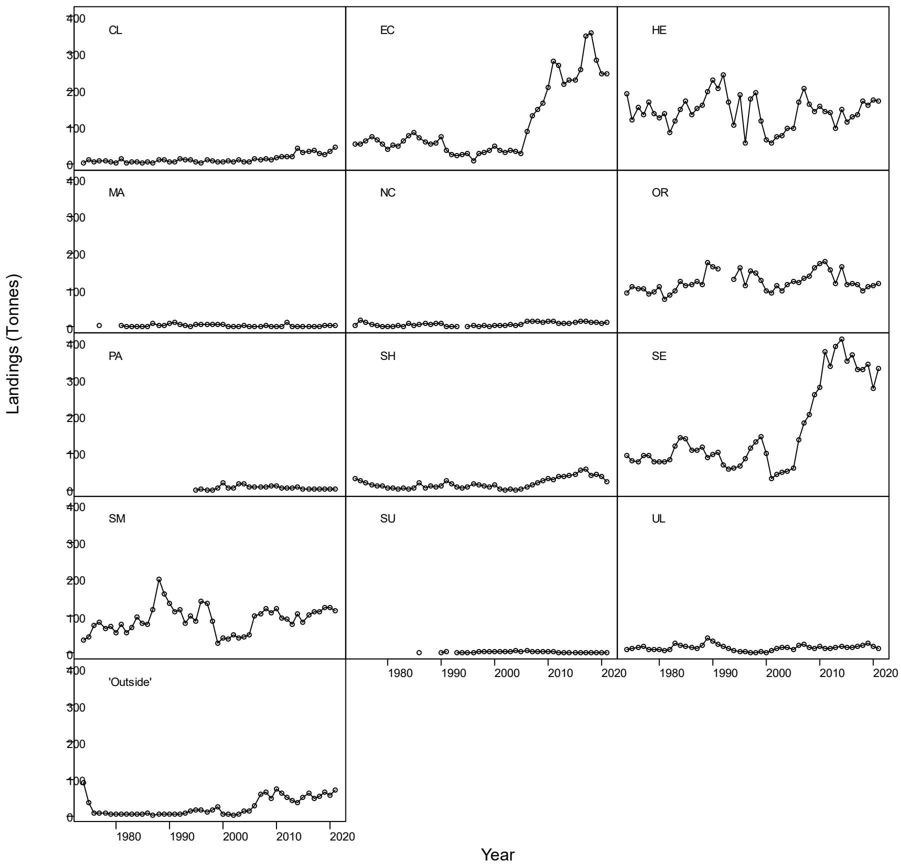


Figure 1.46 .Annual lobster landings (tonnes) into Scotland by fishery assessment unit. 'Outside' relates to lobster landed outside the creel assessment units; see Figure 1 for area locations.

1.16 European lobster (*Homarus gammarus*) in England

Trends in official reported landings (tonnes) and effort (days fished) are reported for lobster *Homarus gammarus* in England. There are six Lobster Fishery Units (LFU) that have been defined for England. These units have been based upon the distribution of the fisheries, hydrographic conditions and what is known of larval distributions and development. Each LFU encompasses waters covered by international, national and local (IFCA) legislation which may be different within each region.

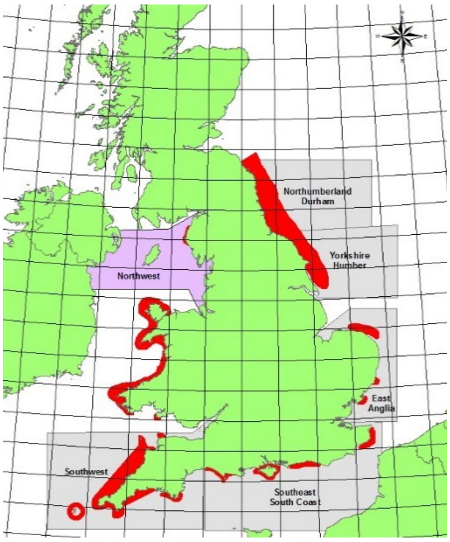


Figure 1.47. Lobster Fisheries Units (LFU's) around England.

Figure 1.48 and Figure 1.49 present the total official landings data. The data pertains to all English and Welsh vessels landing anywhere, and all landings into England and Wales from other UK vessels. Due to changes in the way landings have been reported, care should be taken when comparing back through time. Data from 2010 to present have been collected in a consistent manner. Total landings were stable from 2011-2019 and increased in 2020-2021. The spring of 2018 saw extreme cold weather throughout the country; lobsters began to appear in pots very late in the season and mass mortalities occurred onshore in the North Sea. In 2020-21, Covid restrictions and adjusting to the new requirements for exporters following the UK's exit from the EU affected fishing effort, prices and markets for crab. Another mass mortality event occurred in autumn 2021 in the North Sea, the cause of which remains uncertain.

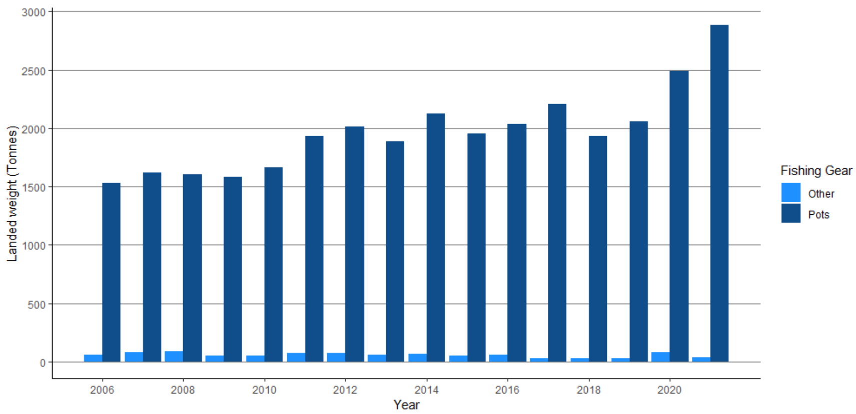


Figure 1.48 .Official landings for UK E&W. Dark blue= landings from pots; light blue= landings from all other gear types.

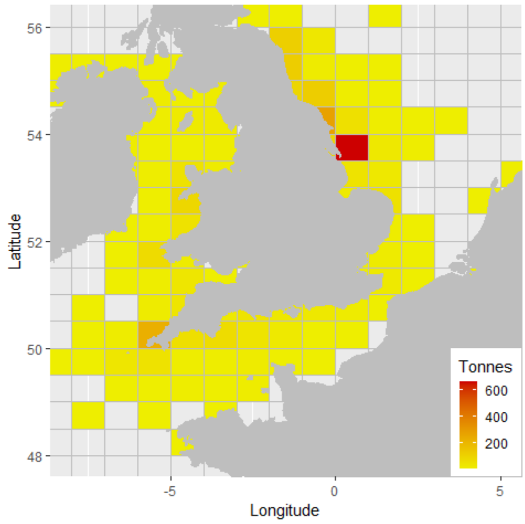


Figure 1.49. Landings per ICES rectangle for 2021.

Landings in tonnes and effort in days at sea is reported for each FU. Reported landings and fishing effort increased substantially following the introduction of Buyers and Sellers legislation and the Restrictive Shellfish License Scheme in 2006 when submission of monthly shellfish returns by fishers was required. Since this period fishing activity data are thought to be generally more reliable but the integrity of the time series, especially fishing effort, is uncertain.

Landings by area are shown in Figure 1.50. Landings of lobster have remained stable since 2012 in Northumberland & Durham with a slight reduction in effort during this period. Yorkshire Humber has seen a large increase in landings in the last three years following a drop in 2018, with effort showing a similar trend. Landings into East Anglia have remained generally stable with a single large peak in 2017. Effort has declined steadily since 2017 in this region. Landings and effort in Southeast South Coast have decreased overall since 2014, with days fished reflecting the fluctuations in landings. Landings in the Southwest have increased significantly since 2018, with effort fluctuating during this period.

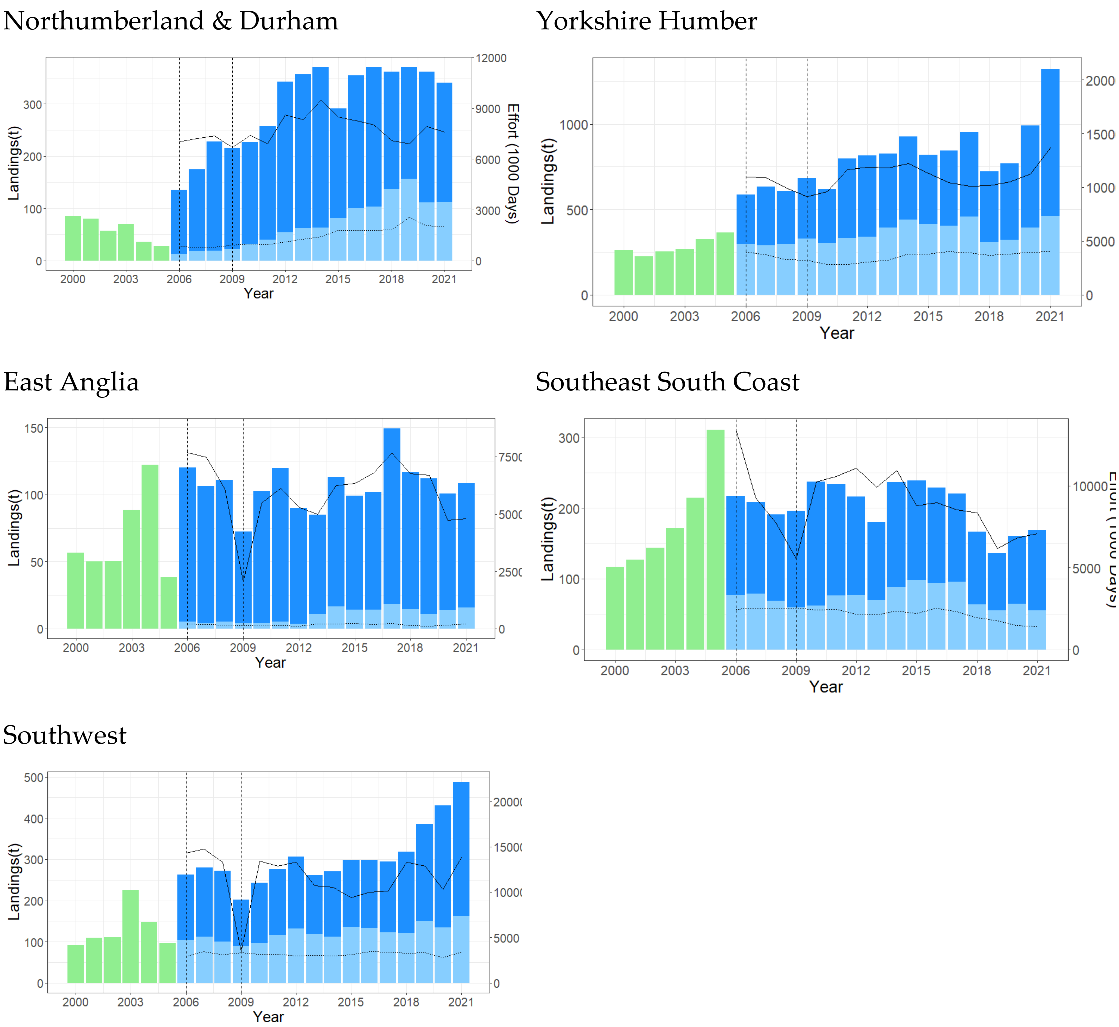


Figure 1.50. Landings (bars) and effort (lines) for <=10m fleet (dark blue/solid line) and > 10m fleet (light blue/dashed line): Note: Changes in recording levels in 2006 and 2009.

1.17 European lobster (*Homarus gammarus*) in Northern Ireland

In Northern Ireland (NI) there is no TAC or quota for lobster. The EU MLS of 87mm is used; no iVMS is available for < 12m vessels other than in Strangford Lough; recreational legislation exists which limits unlicensed fishers to five pots and landings of five brown crab and one lobster per day.

For over 20 years, NI fishermen have been v-notching lobsters as a conservation tool. V-notching involves the notching of the tail of any berried female before returning it to the sea. Any female that has been v-notched is legally protected and should not be landed. This reduces the harvest rate on reproductive females, and, as the v-notch can last several moults, it means the female is protected for several years (two to four years depending on the lobster size). As well as notching berried females, for the last four years NI fisherman have been notching male or female lobsters >126mm. The berries and/or notches are genetically tested allowing not only for a database to be held on lobster families, but also to assess the effectiveness of v-notching as a stock enhancement tool. Full details can be found in the NI lobster science report (McMinn and Prodöhl, 2021).

In 2021, 62.7 tonnes of lobster were landed by NI registered vessels from the ICES rectangles bordering NI (37E3, 37E4, 38E4, 39E3 and 39E4). This is a reduction in landings from a peak in 2014 (86.5 tonnes) (Figure 1.51). Analysis of the effort placed on the lobster fishery shows an overall increase in the number of pots used to land lobsters since 2006, however this has decreased in 2020 and 2021. LPUE for lobsters decreased between 2014 and 2019 but increased in 2020. LPUE is currently just below the time series average.

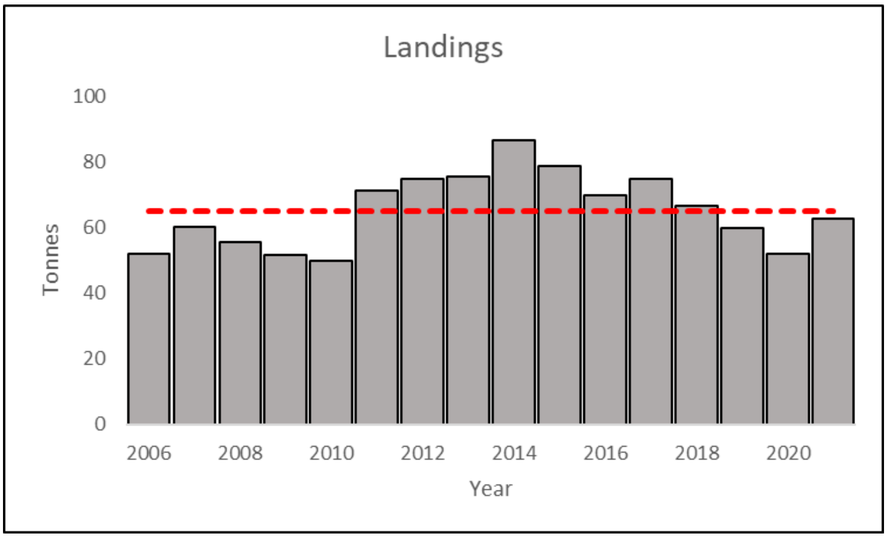


Figure 1.51. Landings of lobster from ICES rectangles 37E3, 37E4, 38E4, 39E3 and 39E4. Red dashed line represents average overtime.

The AFBI run an observer programme for the NI pot fishery, with an average of 19 commercial trips sampled per year. However, in 2022 the number of trips sampled has increased through the Enhanced Inshore project (funded through EMFF) which allowed for a dedicated inshore observer. Observers collect information on the temporal and spatial attributes of the fishery, plus biological information on the species caught.

Using the length data of lobsters collected during observer trips, a length-based model has been developed as an indicator of lobster health. The model shows that whilst the mean size of landed females tends to be above Lopt, 2021 was the first year that males have also been above Lopt.

AFBI produce inshore advice sheets, which set out fishery trends and reference points for all the inshore species. These are provided to the Department of Agriculture, Environment and Rural Affairs (DAERA) for purposes of assisting in the development of future management for the species. For lobster in 2023, the advice is that landings may be increased to 64 tonnes. The full advice sheet for lobster is available at:

https://www.afbini.gov.uk/sites/afbini.gov.uk/files/publications/Lobster%20advice%202023.pdf.

1.18 European lobster (*Homarus gammarus*) in the Isle of Man

The European lobster fishery in the Isle of Man territorial sea has produced between 40 and 60 tonnes of lobster annually from 2007-present (Figure 1.52). Landings in 2022 were 43 tonnes, equal to an increase of 27.8% compared to 2020. Effort in the fishery also increased from 203,000 to 271,000 pot lifts, equal to an increase of 28.8% compared to 2021. The fishery is also monitored using standardised LPUE. The use of standardised LPUE enables the effect of vessel, seasonality of landings, area of operation and capture of other species to be accounted for. In this instance, despite a marked increase in landings, a decline in standardised LPUE was recorded in 2022 compared to 2021, with standardised LPUE being similar to 2019 levels.

Declines in LPUE in the fishery are difficult to verify from logbook data alone, considering that the lobster and brown crab fisheries are reported as a 'mixed' fishery. Following the implementation of inshore vessel monitoring systems (iVMS) in April 2022, more precise spatial and temporal information can be added to logbook data, increasing our understanding and interpretation of long-term trends. In addition, Bangor University is also trialling the use of Baited underwater video systems (BRUV'S) as a method to independently monitor lobster abundance in partnership with industry which will help ground truth perceived changes in lobster abundance reported in logbooks. Bangor University is also investigating stock assessment techniques that can be used to further analytically assess brown crab stocks in the Isle of Man territorial sea.

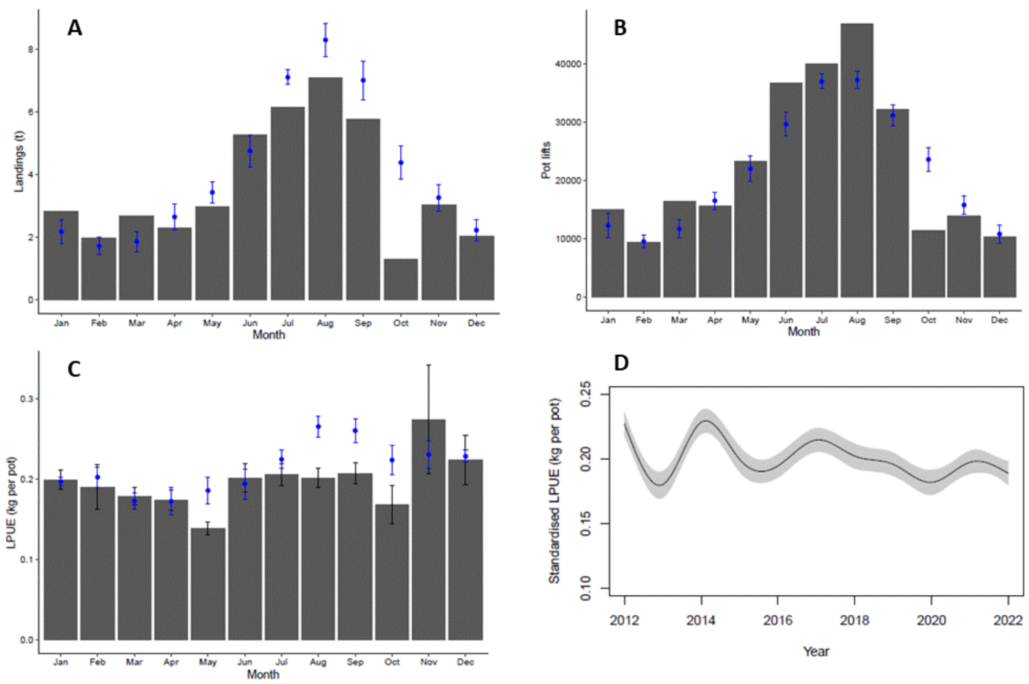


Figure 1.52. European Lobster A) Monthly landings declared in the Isle of Man Territorial Sea throughout 2022 (greys bars) relative to mean values (and standard error) over the reference period 2015 – 2019. B) Monthly pot lifts declared in the Isle of Man Territorial Sea throughout 2022 (grey bars) relative to mean values (and standard error) over the reference period 2015 – 2019. C) Monthly variation in LPUE (Kg/per pot lift) throughout 2022, grey bars relative to mean values (and standard error) over the reference period 2015 – 2019. D) Standardised long term GAM LPUE trend (2012 – 2022) for the Isle of Man territorial sea.

1.19 European lobster (*Homarus gammarus*) in Jersey

1.19.1 The lobster fishery in Jersey

During the last three-year WGCRAB cycle, Jersey has continued to monitor its lobster stocks through both landings and effort data, and independent surveys. This report summarises the key information pertaining to the lobster fishery and provides an update on landings trends.

In Jersey there is no TAC or quota for lobster. Pot fishing in Jersey is currently regulated using a Minimum Landing Size (MLS) of 87 mm carapace width (no max landing size), a pot cap (typically 1000 pots per vessel), and a recreational daily bag limit of 5 lobsters per fisher/vessel. VMS is available for vessels >12 m in length; vessels under <12 m will be required to have iVMS by January 2024.

The European Lobster is at the centre of Jersey's commercial fishing industry. Since at least the late nineteenth century it has been the most important species (in terms of economic value) fished by Jersey vessels. Lobster landings in 2019 (prior to Covid and Brexit) by Jersey vessels were valued at £2.5 million, which was about 35% of the fishing economy although this has been as high as 50% in previous years. Most lobster landed in Jersey, around 85%, are exported to Europe via France either as direct landings from Jersey fishing vessels or via the islands fish merchants. Most fishers sell their catch to local vendors, with prices varying throughout the year between £5 and £28 per kg. Other markets include direct sales to restaurants and the public.

Jersey waters are also fished by vessels from Normandy and Brittany and were, until 1 January 2021, subject to joint management through the Bay of Granville Agreement (GBA). Data provided by Ifremer suggests that the lobster fishery is dominated by Jersey vessels with statistics for the latest available year (2018) suggesting that Jersey vessels landed 190 tonnes of lobster in comparison to 26 tonnes by French vessels (Marine Resources, 2019).

In 2022 Jersey has a commercial fishing fleet consisting of 135 vessels with most being <10 metres in length. Jersey's fleet uses a range of fishing methods but static potting is the dominant metier and is practiced by 90% vessels. A variety of pot types are used by these vessels but parlour pots account for almost 90% of the total fishing effort. Parlour pots are highly efficient and their use is restricted in many parts of Europe. In Jersey waters No Parlour Pot Zones (NPPZs) are currently in place at Les Minquiers, established in 2007, and Les Écréhous, established in 2017 (see Figure 1.9).

1.19.2 Catch data

For the Jersey fleet, lobster catches peaked in 2011 at 262,000 kg and remained mostly above 230,000 kg until 2017 after which a rapid decline is observed (Figure 1.10). There are various ongoing monitoring programs being conducted by the Marine Resources team to better understand long-term changes in lobster stocks. These datasets include:

- Commercial logbook data (2007-Present)
- Annual spring potting studies (2004-Present)
- Autumn potting studies in Marine Protected Areas (2018-2020)
- Quayside measurements (2019 to present)

The commercial fleet has submitted daily effort and catch statistics since 2007 in the form of logbooks. These logbooks are received quarterly and are mandatory for all licenced Jersey fishing vessels. Weights are in KG and are recorded for one of six zones. Effort is recorded in the number of pot lifts for each type of pot (inkwell, parlour pot, creel and D pot). Total landings dropped in 2020 to the lowest point since logbooks were brought into place as a licence condition for Jersey fishing vessels in 2007 (111t) (Figure 1.53). Effort was also reduced resulting in an LPUE drop to 8.9kg of lobster caught per 100 pots hauled (Figure 1.54). Marine Resources hold sporadic annual catch statistics going back to the 1960s. Data from the 1980's onwards, combined with the daily catch recording from 2007, are shown in Figure 1.53.

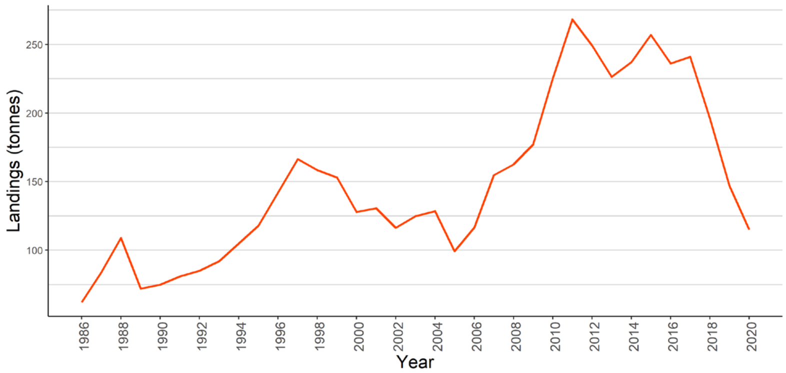


Figure 1.53. Commercial lobster landing data from 1986-2020. Based on fishers logbook entries from 2007.

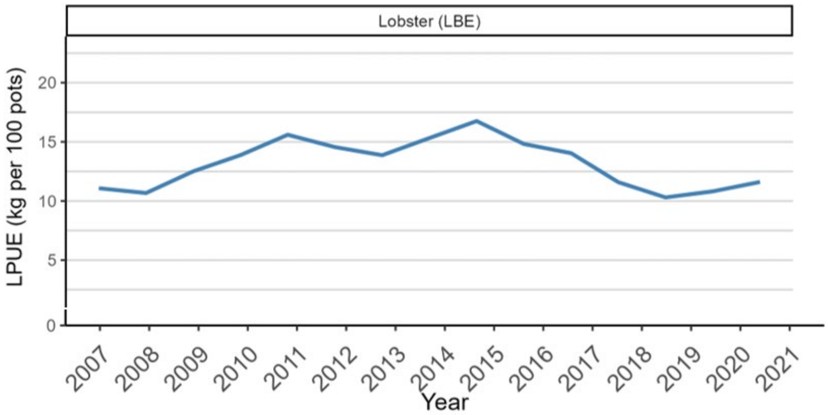


Figure 1.54. Total landed weight and LPUE (kg/100 pots) for the Jersey commercial lobster fishery between 2007 and 2021

The use of Lobster pots has been decreasing since 2017 which is primarily driven by the decline in use of parlour pots (Figure 1.55). The lowest number of pot lifts recorded was in 2021 at around 1 million pot lifts.

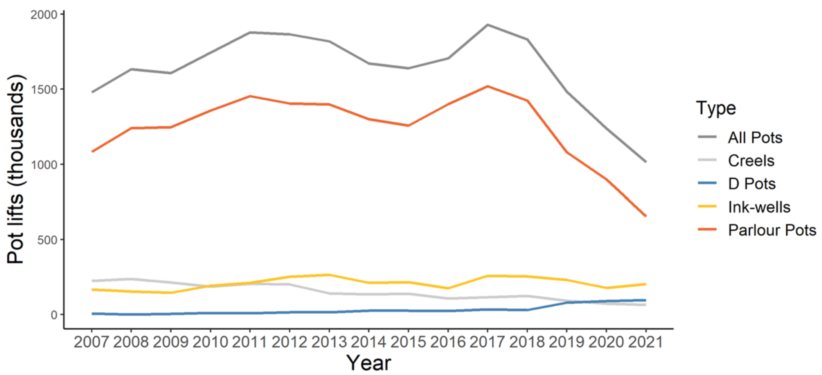


Figure 1.55. Number of thousand pot lifts for different pot types used per year in the Jersey commercial lobster fishery between 2007 and 2021.

1.19.3 Annual potting surveys

Annual trials have been conducted from 2004 to the present day as an annual two-week survey split across May and June. The same three locations (Figure 1.13) are fished using adapted parlour pots with closed escape gaps and a smaller mesh to capture and record juvenile lobsters each year. Following a 48-hour soak, the pots are recovered and all shellfish are measured, sexed and assessed for maturity based on morphological development (relative crusher size and abdomen width). For all caught animals, measurements are made of the abdomen width, carapace length and claw dimensions with the sex, berried status, any damage and disease being recorded.

The mean number of lobsters caught per pot steadily increased until 2011 for sized (>MLS) lobsters and until 2017 for undersized (<MLS) lobsters, after which both have been in decline, with the rate of decline much steeper for undersized (Figure 1.56). In all years, mean number of undersized lobsters was greater than those above MLS.

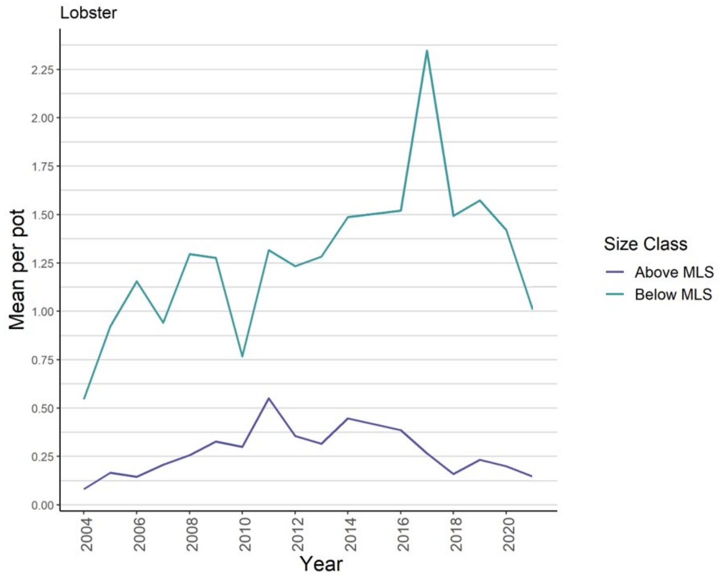


Figure 1.56. The mean number of lobster individuals in each size class caught per pot between 2004 and 2021.

Figure 1.57 presents the size distribution of lobsters caught in the annual trials between 2004 and 2020. The frequency of lobster above and below MLS (87 mm) appeared stable but with a drop off in frequencies above MLS in most years.

From 2018, an additional potting survey (during autumn) was introduced at Les Écréhous and Les Minquiers as part of a PhD project (Blampied, 2022) to assess the commercial crustacean populations at the offshore reefs. Pots were set across three separate management areas: Marine Protected Areas (where mobile gear is excluded); No Parlour Pot Zones, and Open fishing areas. The results showed a general decline in lobster across treatments except for within one MPA where there were significantly greater numbers of below MLS lobsters. The full study is available on request.

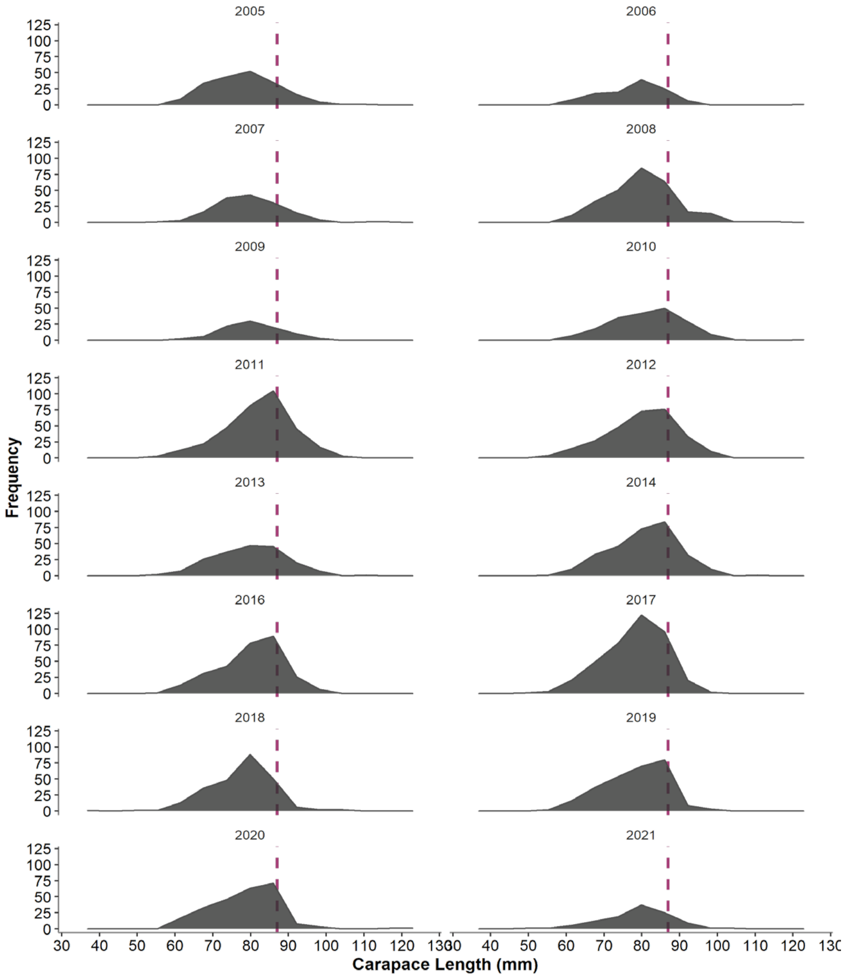


Figure 1.57. The size distribution of lobsters caught in the annual trials between 2004 and 2021. MLS shown by the dashed vertical orange line.

1.20 European lobster (*Homarus gammarus*) in Ireland

Over the last three-year WGCRAB cycle, Ireland has continued to update and review the different data sources available for the assessment of lobster populations. This document provides the latest update on stock status indicators. The lobster fishery in Ireland is managed using technical measures. The minimum size is 87 mm carapace length. A maximum size limit of 127 mm was introduced in 2015 following an egg per recruit assessment which showed low egg production and to protect v-notched lobsters growing into larger size classes. It is prohibited to land v-notched lobsters. The number of v-notched lobsters released annually was 5,000-11,000 individuals during 2002-2008, 10,000-15,000 during 2010-2013 and 25,000-33,000 annually during 2014-2021. The v-notching of lobsters is voluntary. There is no limit on fishing effort or catch.

Lobsters are probably distributed as regional stocks along the Irish coast. This has been shown by larval dispersal modelling. Juvenile and adult lobsters do not move over large areas and the stock structure is determined mainly by larval dispersal. Genetic and larval dispersal modelling studies are ongoing through a project that will indicate the range of dispersal of progeny from v-notched lobsters released in different areas between Loop Head and Slyne Head.

1.20.1 Sampling programmes

In Ireland, there are three main sampling programmes that provide the majority of information used to review stock status. These are:

- Sentinel Vessel programme (SVP): the SVP programme is a self-sampling scheme administered by the Irish Seafood Development agency (BIM) as a pilot project funded by the Data Collection Framework. Vessels are chosen from different length and gear categories representative of fishing activity by vessels under 12 m around the Irish coast, covering around 8% of the fleet. The data recorded in SVP logbooks include the catches, landings and discards of several species on a daily basis as well as operational fishing information (fishing location at either ICES Statistical Rectangle or Inshore Grid Resolution, type and amount of bait used or vessel operating costs).
- Skipper self-sampling programme (since 2021); Skippers observer type data for a given number of trips per year. The data is at operational level and includes details of undersized, legal sized, oversized and v-notched lobsters and by-catch and size frequency data.
- Marine Institute Observer programme: every year, Marine Institute observers, record catch, effort, and biological information for every haul on a number of commercial inshore trips (~40-70 trips per year). This dataset provides the main source of size distribution information at a local level, for many lobster-fishing areas.

The coverage of all programmes, however, is considered to be insufficient to provide precise estimates of catch rates at local level given the variability in these data in time and space. Based on the data sources described above, two lobster stock indicators are reviewed on an annual basis:

- Catch rates (LPUE,DPUE,VPUE,OPUE) from the SVP and observer programme, and
- Lobster reproductive potential based on size distribution data from the observer programme

1.20.2 Stock status

Reproductive Potential

The reproductive potential (RP) of a given size class of lobsters is the product of the number of lobsters in the size class, the probability of maturity, spawning frequency and size related fecundity. It is a measure of the relative contribution of different size classes and v-notched or non-v-notched components of the stock to overall reproduction. An indicator of the implementation and effect of the v-notch programme should be evidenced through changes in RP of the v-notch component of the stock relative to non-v-notched components. Similarly, changes in RP of lobsters over the Maximum Landing Size (MaxLS) may increase over time as lobsters' escape fishing mortality and grow above 127 mm.

On average across years, 15-20 % of RP is in lobsters below the minimum landing size of 87 mm (Figure 1.58, Figure 1.59 and Figure 1.60). A further 50-60 % is in lobsters between 87-127 mm, which is the size range that is fished. V-notched lobsters generally account for 10-20 % of the RP. In 2021 observer data showed that lobsters below 87 mm accounted for 19 % of RP, lobsters in the fishable size range accounted for 50 % of RP, v-notched lobsters in that size range accounted for 20 % of RP and the remainder of RP was in lobsters over 127 mm (8.5 % in v-notched lobsters over 127 mm and 1.5 % in lobsters over 127 mm that are not v-notched). There are significantly higher contributions in 2021 by v-notched lobsters both in the 87-127 mm size range and also above the 127 mm maximum size limit. Observer data in 2021 is less comprehensive than in 2020 and some differences may be accounted for by poorer sampling coverage. The data from the new skipper self-sampling programme established in 2021 have yet to be incorporated into these figures.

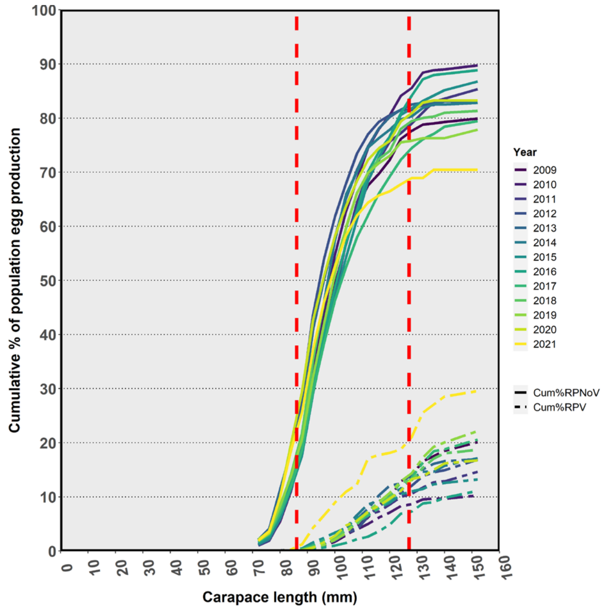


Figure 1.58. Cumulative distribution of reproductive potential (RP) across size classes of V-notched and non-V-notched lobsters all regions combined. Source: Marine Institute Observer data 2009-2021.

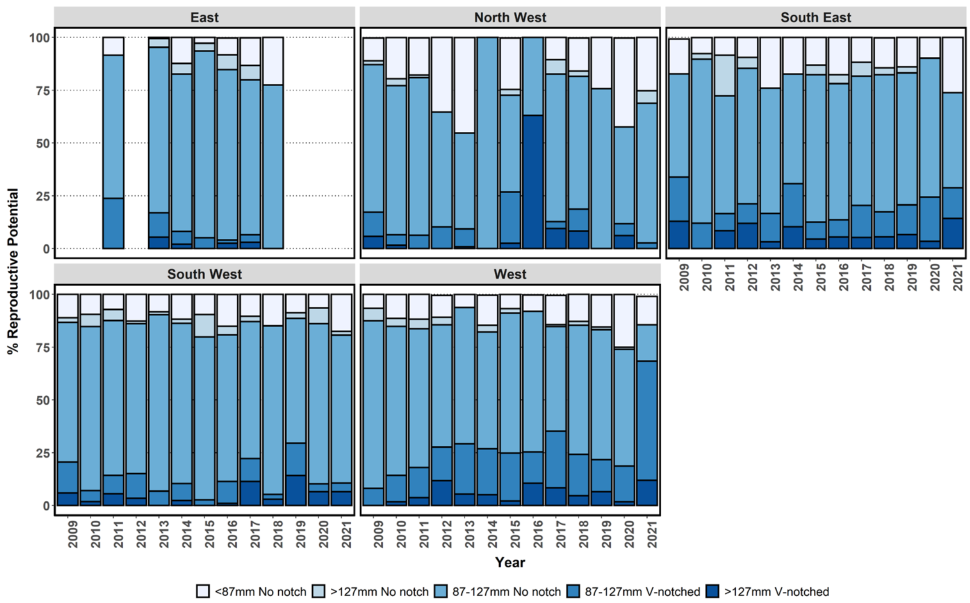


Figure 1.59. Summary of the distribution of the % reproductive potential in lobster stocks conserved by v- notching, minimum size and maximum size measures by region. Marine Institute Observer data 2010-2021.

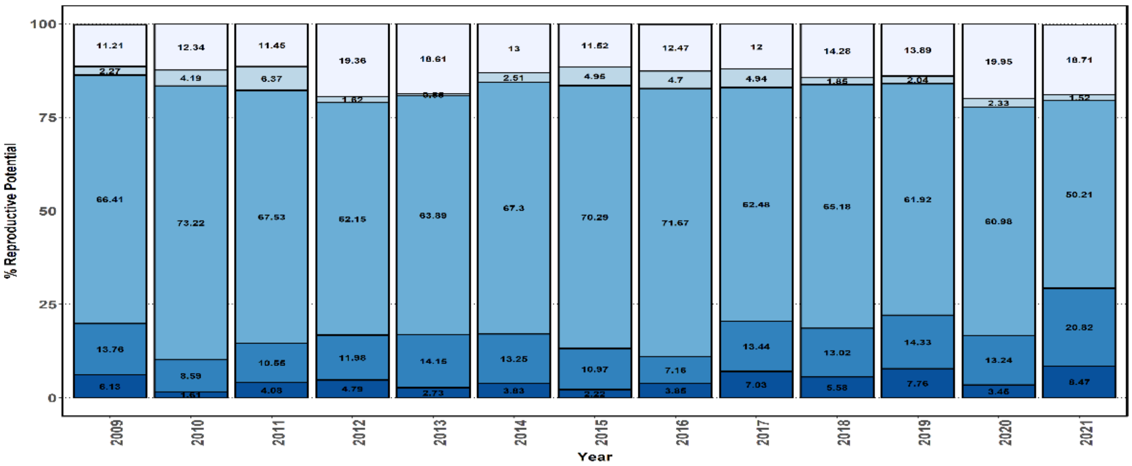


Figure 1.60. Summary of the distribution of the % reproductive potential in lobster stocks conserved by v- notching, minimum size and maximum size measures for all regions combined. Source: Marine Institute Observer data 2010-2021.

Catch Rates

This report includes the SVP data from 2013-2020 and the MI observer data from 2014-2021. Before 2014, observer trips were very limited and thus, catch rate data are not shown. SVP data and data from various earlier voluntary logbook programmes prior to 2013 are being compiled. In the SVP, lobsters are generally reported in either numbers or kilograms. Numbers are reported in this analysis. Weights were transformed to numbers based on the modal size of lobsters (106 mm) from observer data. A length-weight relationship from port-processor data was applied ($\mathbf{W}=1.42*10^{-6}\mathbf{L}^{2.84}$) where W is weight and L is carapace length.

The catch rates of legal (LPUE) lobsters and underside (DPUE) lobsters from 2013-2021, all areas combined, were stable (Figure 1.61, Figure 1.62). Observer data generally reports higher catch rates, especially for the discarded component. Seasonally, LPUE generally peaks in quarter 3 and declines in quarter 4. This is probably a combined effect of in season landings and reduced catchability, related to declining temperatures, later in the year.

Size composition

The annual size composition data of discarded and landed lobsters remains stable (Figure 1.63). The number of lobsters measured in the observer programme however has declined in recent years.

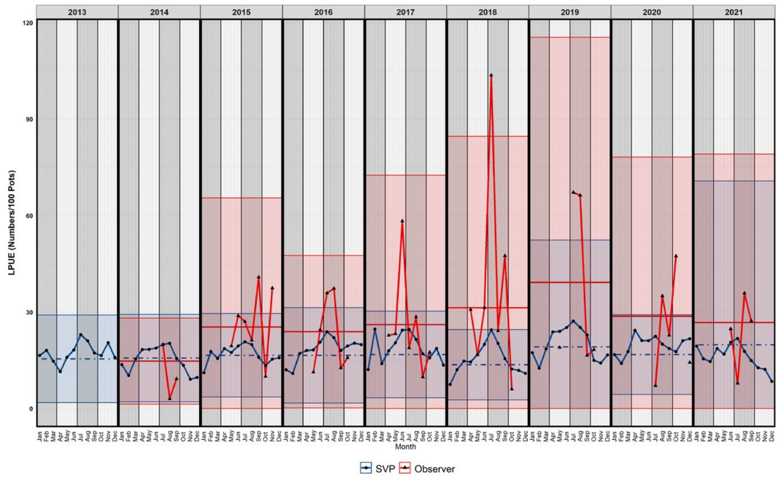


Figure 1.61. Annual mean landings of lobster per effort (100 Pots) for the SVP (2013-2021) and MI Observer programme (2014-2021).

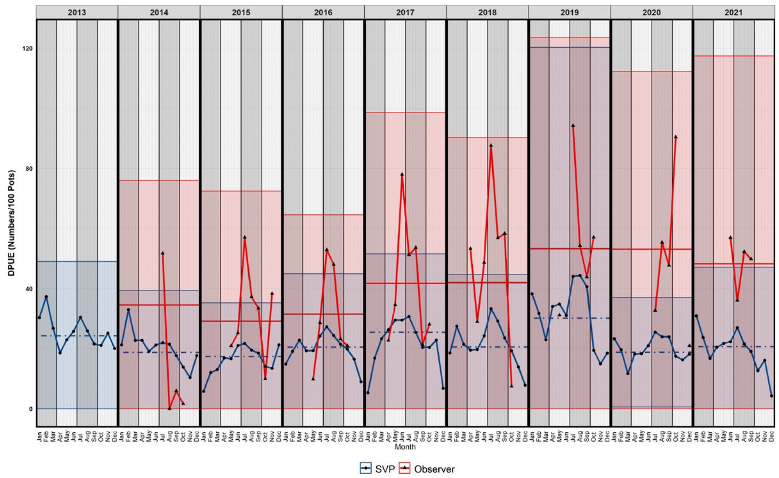


Figure 1.62. Annual mean landings of lobster per effort (100 Pots) for the SVP (2013-2021) and MI Observer programme (2014-2021).

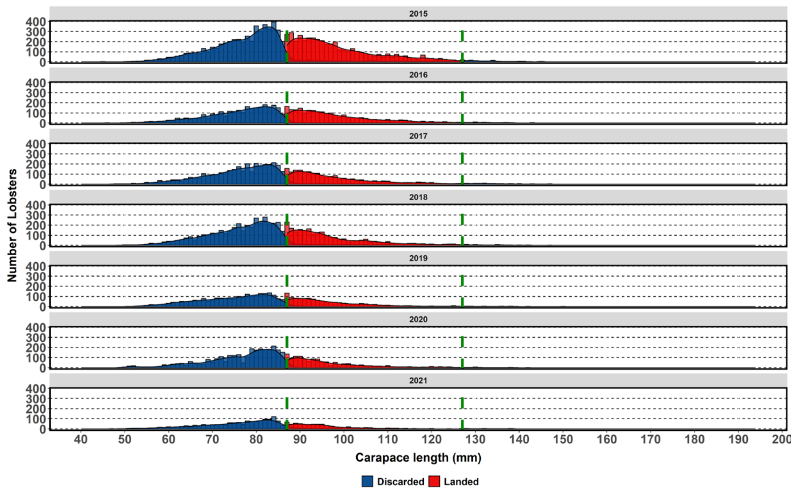


Figure 1.63. Annual size distributions of discarded (<87 mm, >127 mm) and landed lobsters across all regions. Marine Institute observer data 2015-2021.

1.21 European lobster (*Homarus gammarus*) in France

1.21.1 Landings, effort and catch data

The French lobster fishery is mainly linked to the use of pots as fishing gear accounting for more than 85% of the landings. The other portion of the landings come from gillnetters and at a lower level, trawl vessels. This fishery is mainly located in shallow water (0 – 50 meters) along the French coast (Western and Eastern Channel and Bay of Biscay) on rocky grounds. The landings from the gillnetters are mainly composed by individuals weighting more than one kilogram, which are considered as big lobsters. The annual landings are seasonal with a peak between May and July. The legal MLS is 87 mm carapace length but there are currently discussions to increase this to 90 mm. The Eastern Channel area has implemented this new MLS in 2021. After the MLS, the two main regulations in this fishery concern the access to the fishery with a maximum number of vessels allowed inside each fishing area (controlled with fishing licences) and limited numbers of pots per fishermen on-board. Moreover, the pots have to comply with certain size guidelines and parlour pots are mostly banned, excepted in some areas with specific rules.

During the last decade, the annual landings have fluctuated from 500 to 720 tonnes (Figure 1.64). In the last two years, landings have stabilized around 600 tonnes. In 2020, the Covid crisis appeared to have a low impact in the lobster fishery with only a decrease of 50 tonnes compared with the previous year. From 2000, the increased trend in landings until 2010 should be interpreted with caution due to the improvements in the French declaration system for fishing data. Since 2010 close to 100% of the fishermen started to declare their landings and fishing activity on a daily basis with fishing sheets. The annual number of vessels involved in the fishery is above 1000 but vessels with an economical dependence on the lobster (annual catch >= 500 kg) are estimated around 300, and landings for these have remained relatively stable.

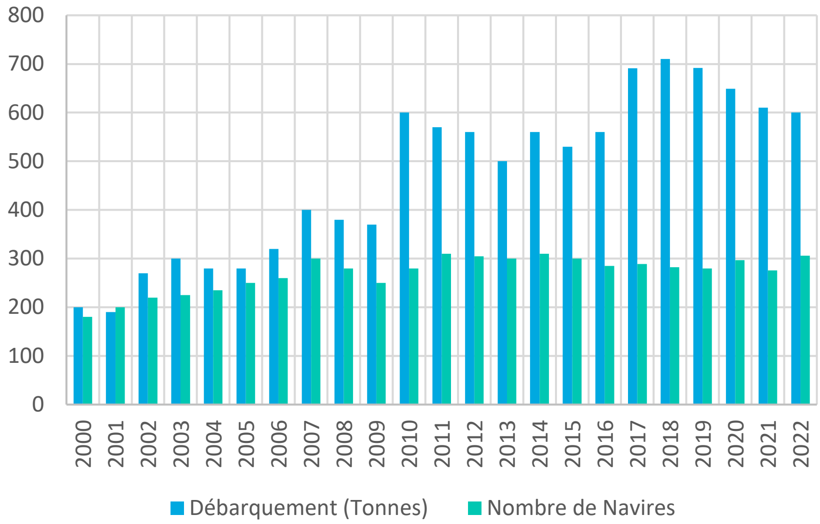


Figure 1.64. French landings of lobster and number of vessels targeting lobster (more than 500 kg per year).

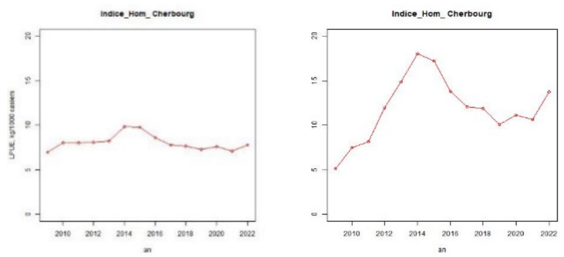
1.21.2 CPUE indicators of lobster in France

The total lobster production and effort were estimated from the daily fishing sheets. These data are stored in the national database and these datasets are considered to be of high quality, allowing for CPUE/LPUE analyses. From these data, an LPUE index was calculated on a daily basis for each vessel and this was used to estimate a global LPUE index by fishing area. A GLM model was applied to produce the LPUE index, where the variables used were the following: year, month, fishing area, and vessel ID. A log transformation of the LPUE was applied and a gamma distribution considered.

The general trend for the main lobster areas seems to show different scenarios (Figure 1.65). In the east part of the English Channel from Saint Malo to Boulogne quarter, the LPUE index trend have increased between 2011 and 2016 before a decrease until 2021. In the three areas, the situation seems to be better in 2022. The Boulogne area shows a slightly different global trend with an increase of the LPUE index along the time series. West of these areas, from Paimpol to Guivinec, the trend shows generally a slight increase despite some annual variation. In the south Brittany and Loire Atlantic, the trend shows a clear increase in the 10 last years. During two last years, a gradual change occurred in the quarters from Brest to Croisic with the decrease explained by a change in the fishing strategy. In fact, the huge quantity of Octopus (*Octopus vulgaris*) has led many vessels to target this species for economic reasons (high prices and high daily landings. The stock status for lobster is considered to be generally good despite no length-based indicators or other stock assessment being yet available for these stocks. For the coming years, assessments will be fitted using a surplus model such as the SPiCT model.

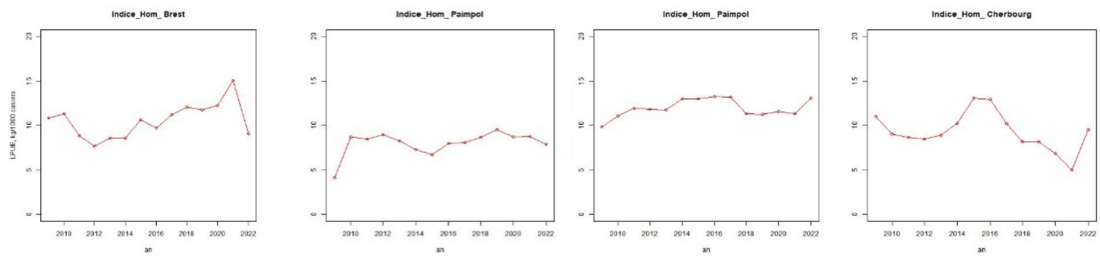
Eastern Channel

Cherbourg Quarter | Boulogne Quarter



Western Channel- North Brittany Areas

Brest Quarter | Morlaix Quarter | Paimpol Quarter | Saint Malo Quarter



Bay of Biscay – South Brittany Areas

Guilvinec Quarter | Concarneau Quarter | Lorient Quarter | Croisic Quarter

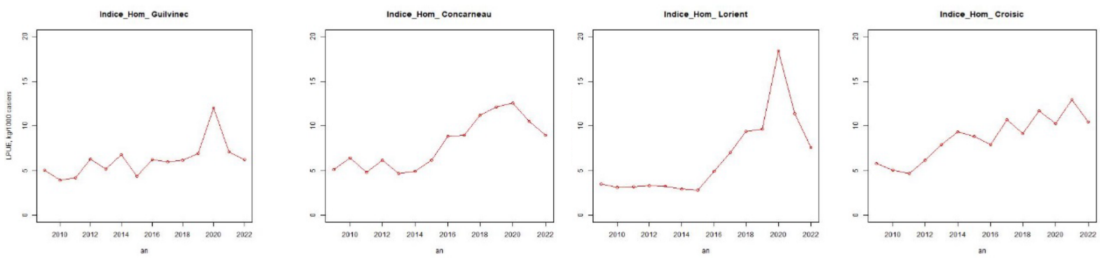


Figure 1.65. LPUE index by lobster fishing area.

1.22 European lobster (*Homarus gammarus*) in Norway

1.22.1 The Norwegian lobster fishery

The lobster fishery in Norway has a long history dating back to at least the 16th century. Landings data based on export statistics are available from 1816 onward, and from 1875 total landings were documented (Figure 1.66). Before 1908, landings were registered in numbers of individuals, while later landings data represent total weight. Norway introduced a national register for sales slips in 1977 that contains information on the catch area. Prior, to 1977, only landing locations were registered, however due to localized nature of the lobster fishery this is assumed to approximate the fishing area. The stock is currently considered to consist of three functional units – Skagerrak, Western Norway, and north of 62°- that are largely defined by differences in data availability, fishing patterns and geographical features that tend to mitigate migration between areas.

Annual commercial landings of lobster in Norway have fluctuated over time at around 200 – 500 t, with a maximum peaking well above 1000 t in the 1930s. From the 1960s onward, commercial lobster landings steadily declined to 40 – 60 t during the past decade. The decrease in commercial landings coincided with an increase in recreational fishing of lobster. However, because recreational fishers do not have any reporting duties in Norway, recreational landings over time are unknown. A mandatory registration for lobster fishing was introduced in 2017, allowing to quantify participation (more than 34 000 recreational fishers) and estimate recreational landings through targeted surveys (Kleiven *et al*., 2019). The estimates indicate that recreational fishers land more than two thirds of total catches. Official landing statistics represent therefore a substantial underestimation of total removals.

There is currently no stock assessment or advisory framework for lobster in place. Subsequently, the fishery is mostly regulated through input regulations (limits of 100 and 10 pots for commercial and recreational fishers, respectively; fishing season from October 1st to November 30st (December 31st north of 62° north); lobster protection areas) and minimum and maximum landing sizes, and protection of egg-bearing females. Restrictions on season and landing size were introduced in the 19th century but were gradually tightened. Registration has been mandatory since 2017 but entails no limits on participation. Possible total fishing effort and total catches are therefore not limited but indirectly by catch rate and economic constraints.

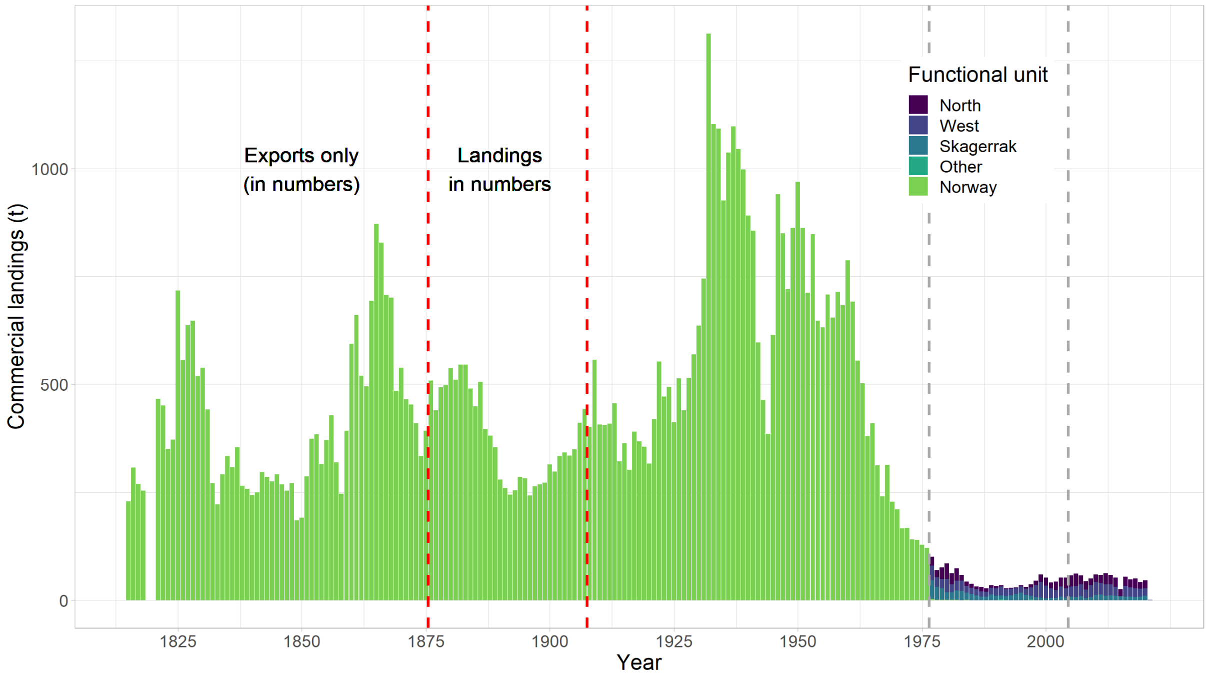


Figure 1.66. Total commercial landings of Homarus gammarus in Norway per region (functional unit) from 1816 to 2021, based on information from Statistics Norway (prior to 1977) and landing slips register from the Directorate of Fisheries.

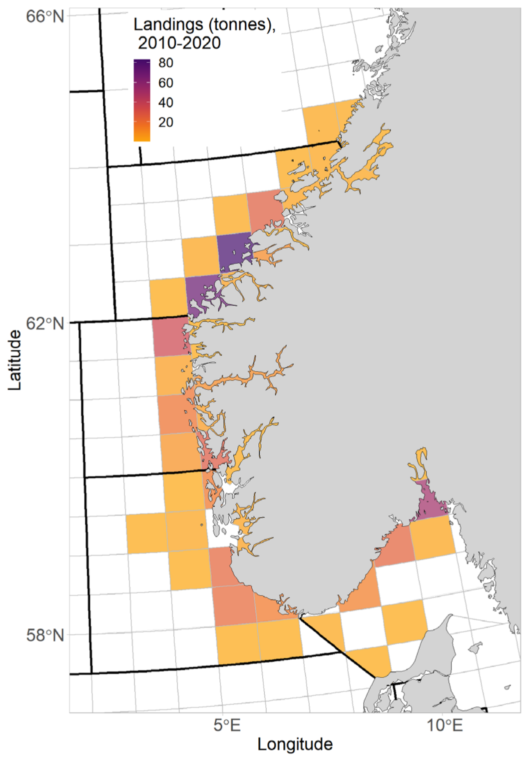


Figure 1.67. Distribution of commercial landings of Homarus gammarus summed over the period of 2010-2020 per statistical location where catches originated. Colors indicate total landings, dark solid line border of statistical areas.

1.22.2 Stock status

The lack of reliable information on total catches or comprehensive survey coverage of entire functional units has prevented an analytical assessment of the stock so far, and stock status is, thus, uncertain. However, multiple datasets are available that can provide qualitative information on stock trends on different spatial scales. The longest time series are self-reported seasonal CPUE data (number of lobster caught per season and number of traps) and lobster measurements from volunteer fishers dating back to 1928, mostly from the Skagerrak. More recently, recreational and commercial fishers were recruited to report trip-based information on fishing effort and catches (since 2008) and probability-based surveys of fishers based on the registry were conducted since 2017 to gain information on total participation and catches in the fishery. In addition, several lobster reserves have been monitored since their establishment, providing controlled case studies on lobster dynamics with and without fishing pressure.

A major obstacle to utilizing long CPUE time series for stock assessment purposes was that relevant information for standardization was not registered. This concerns mostly substantial technological creep during a century, especially due to pot development. An empirical study was therefore conducted to assess historic use of different pot types and their catchability, combining this information in a probabilistic generalized linear mixed model to standardize CPUE (Kleiven *et al*., 2022). The resulting index indicates a decrease of 92% since 1928 (in contrast to 70% without accounting for technological creep) (Figure 1.68). Although there is some uncertain how CPUE of a pot fishery corresponds to changes in abundance, and several potential drivers of changes in CPUE could not be accounted for (spatial expansion of the fishery and shifts to deeper areas, changes in regulations), the standardized CPUE index provides to date the best indicator of long-term changes in the lobster stock. It can therefore be concluded that lobster in Norway is overfished and subject to overfishing, particularly in the Skagerrak FU where most of the data originates from. This is corroborated by available data from lobster reserves that show a substantial increase in lobster abundance in areas without fishing (Knutsen *et al*., 2022).

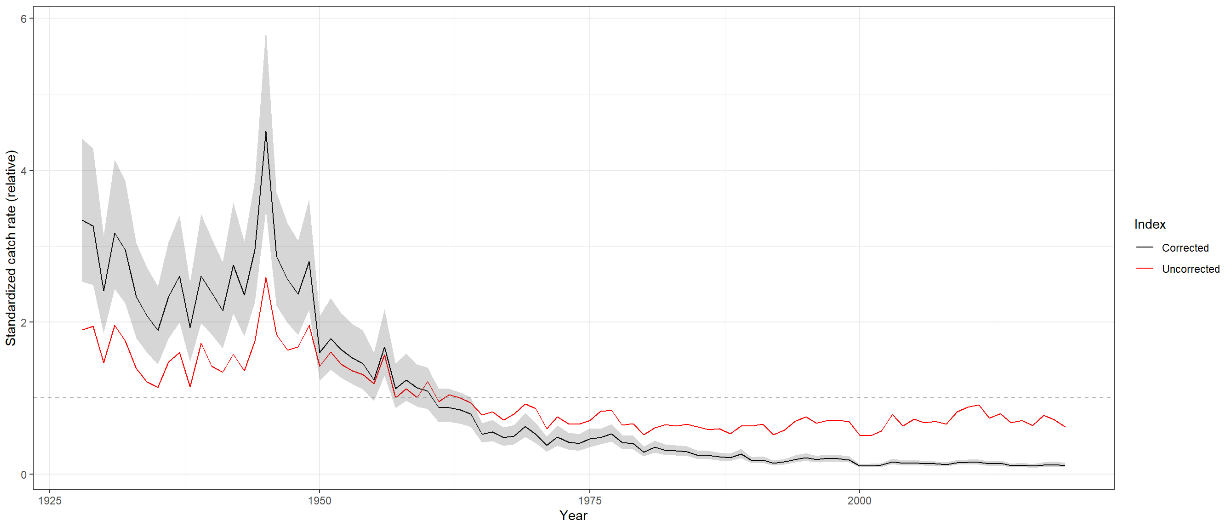


Figure 1.68. Standardized CPUE indices corrected for technological creep (black) and uncorrected (red). CPUE data is based on self-reported seasonal landings of volunteer fishers.

1.22.3 Stock assessment work and future research

It is an objective to establish an analytical stock assessment framework for lobster in Norway and provide advice. Different assessment methods have or will be explored, including surplus production models such as SPiCT (Pedersen and Berg, 2017) and length-based methods such as LBSPR (Hordyk *et al*., 2014). Preliminary results were presented during the WGCRAB meeting but are not included in this report. Data limitations and unsuitable specifications of many standard models for the characteristics of the lobster fishery (passive gear fishery with minimum and maximum landing sizes) were identified as key obstacles. Current research is therefore focussed on improving the availability and quality of input data. This includes reconstructing total landings and evaluating methods to do so, improving knowledge on ghost fishing as a source of mortality, integrate historic CPUE index with newer time series with higher resolution, and generate information on life-history parameters and population dynamics priors from available data.

2 ToR b) Stock Assessment

Full ToR b) The EG will collate stock assessment data for areas where the information is available. The working group will review methodologies to develop suitable standardized reference points for the management of the different stocks. Explore and apply common assessment methods for crab and lobster stocks using available data including length distributions and abundance indices.

WGCRAB members have responded positively to the request made in 2020, at the beginning of 3-yeear term, for considering the data available for their respective stocks and attempt to run stock assessment methods aiming to provide stock status for their local fisheries. An assessment sub-group has been established and 3 WGCRAB interim meetings were arranged in 2022 focused on stock assessments, where participants presented and provided feedback on the methodologies used. By the third year, the group had preliminary stock assessments presented for brown crab and European lobster in several countries using length-based methods and production models. It is expected that in the coming years more assessments will be put forward to the group.

An introductory presentation was given on the surplus production model in continuous time (SPiCT) model by one of the developers of the R package who has been collaborating with ICES on other fish stock assessments. SPiCT (Pedersen and Berg, 2017) is widely used within ICES for the provision of advice for ICES Category 2-4 stocks. The main aim of this presentation was to give a high level introduction of SPiCT, focused on the main assumptions of the model, required and optional input data, main outputs, and model checking. Additionally, two examples were shown illustrating exploitable biomass correction and use of quarterly catch data. Recent SPiCT developments were described in two scientific publications (Mildenberger *et al*., 2020; Mildenberger *et al*., 2022) and two working documents (Mildenberger *et al*., 2021; Pedersen *et al*., 2021) that were shared with the group. The presentation was very well received and encouraged other WGCRAB members to run this model on their available data. Following this, in 2022 members presented and discussed stock assessments of brown crab and/or lobster stocks in Ireland, Scotland, England, Northern Ireland, Jersey, Wales, France, Norway and Canada stocks using length-based methods or production models and SPiCT. In addition, WGCRAB Scientists from England and France collaborated and presented the first integrated length-based stock assessments for brown crab in the Western Channel using length-based assessment methods. This followed from an ICES data call released in 2021 requesting ICES member countries participating in the fishery to submit landings, length and fishing effort data. This ToR was carried over to the next resolution (2023-2025) and is expected to continue to be a key discussion point in the WGCRAB meetings. An additional ToR related with stock assessment biological parameters is expected to feed into this topic (see Section 4).

2.1 Brown crab SPiCT assessment in Ireland

2.1.1 Malin Stock Assessment

The data used in the assessment of the Malin Stock included the time series of landings and two independent biomass indices. All the R-code developed for this assessment is available in the following public github repository: https://github.com/gfmg/BrownCrab_IRL-NW

Data sources (see Section 0) were limited to the ICES rectangles shown in Figure 1.16. Landings, as well as sampling information for vessels under 10m which did not report the ICES Rectangle were limited to ICES Areas 6a and 7b, or Counties Donegal, Mayo and Sligo when the ICES Area was not available. Even though, the extension of ICES Area 6a and 7b (as well as the county limits) expands beyond the ICES Rectangles shown in Figure 1.16, fishing operations for vessels under 10m are known to occur within the proposed study area limits.

Several SPiCT scenarios were developed as part of the stock assessment process. Table 2.1 summarizes each scenario setting, while Table **2.2** presents SPiCT diagnosis outputs as suggested in model manual (https://github.com/DTUAqua/spict). Across scenarios, model convergence was generally achieved (with exception of R8 in **Table 2.2**), consistent trends and model outputs were obtained, and model validation points were accepted. Final model settings (Scenario G2) and reasoning behind main model decisions are summarized below.

Table 2.1. SPiCT model settings for the different scenarios implemented

Scenarios	Landings	SVP_LPUE_Fleet	LPUE index	Uncertainty	Priors
F1	2002-2019	Above 8m	SVP: 2005-2019 (-2008)	default	-
F2	2002-2019	Above 8m	SVP: 2005-2019 (-2008)	default	inpinilogn <- log(2) inp$phases$logn <- -1
F3	2002-2019	Above 8m	SVP: 2005-2019 (-2008)	default	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.7), 0.5, 1)
F4	2002-2019	Above 8m	SVP: 2005-2019 (-2008)	inp$stdevfacC <- rep(1, length(inp$obsC)) inp$stdevfacC[1:5] <- 2	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.7), 0.5, 1)
F5	2002-2019	Above 8m	SVP: 2005-2019 (-2008)	inp$stdevfacC <- rep(2, length(inp$obsC))	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.7), 0.5, 1)
F6	2002-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(2, length(inp$obsC))	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.7), 0.5, 1)
F7	2002-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 2002-2006	inp$stdevfacC <- rep(2, length(inp$obsC))	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.7), 0.5, 1)
R8	1990-2019	Above 8m	SVP: 2005-2019 (-2008)	default	-
R9	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	default	-
R10	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(1, length(inp$obsC)) inp$stdevfacC[1:13] <- 2	-
R11	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(1, length(inp$obsC)) inp$stdevfacC[1:13] <- 2	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.9), 0.5, 1)
R12	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(2, length(inp$obsC))	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.9), 0.5, 1)
R13	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(2, length(inp$obsC)) inp$stdevfacC[1:13] <- 4	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.9), 0.5, 1)
G1	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(2, length(inp$obsC)) inp$stdevfacC[1:13] <- 4	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.9), 0.5, 1) inp$priors$logr <- c(log(0.3), 0.2)
G2	1990-2019	Above 8m	SVP: 2005-2019 (-2008) Vivier: 1991-2006	inp$stdevfacC <- rep(2, length(inp$obsC)) inp$stdevfacC[1:13] <- 4	inpinilogn <- log(2) inp$phases$logn <- -1 inp$priors$logbkfrac <- c(log(0.9), 0.5, 1) inp$priors$logr <- c(log(0.3), 0.5)

Table 2.2: SPiCT scenarios diagnosis

		F1	F2	F3	F4	F5	F6	F7	R8	R9	R10	R11	R12	R13	G1	G2
Convergence		4	5	4	5	5	5	4	8	5	4	5	5	4	4	4
Diagnostics																
Bias	Catch	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	SVP	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	Vivier	-	-	-	-	-	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
Normality	Catch	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	SVP	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	Vivier	-	-	-	-	-	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
Autocorrelation	Catch	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	SVP	Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	Vivier	-	-	-	-	-	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass
Retrospectives																
Mohn's rho	B/Bmsy	1.178	0.956	0.954	0.364	0.956	-0.453	0.664		0.013	-0.003	-0.049	-0.002	-0.048	0.125	0.018
	F/Fmsy	-0.649	-0.624	-0.616	-0.257	-0.617	-0.244	-0.512		-0.032	-0.015	0.038	0.004	0.038	-0.230	-0.070
Model Checks																
Variance Parameters finite		TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE		TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Realistic production curve		0.426	0.5	0.5	0.5	0.5	0.5	0.5		0.553	0.558	0.5	0.5	0.5	0.5	0.5
Uncertainty																
B/Bmsy magnitude		0	0	0	0	0	0	0		0	0	0	0	0	0	0
F/Fmsy magnitude		0	0	0	0	0	0	0		0	0	0	0	0	0	0
Sensitivity check.ini(,ntrials=30)		Fail 5/30	Fail 3/30	Pass	Pass	Pass	Pass	Fail 1/30		Fail 1/30	Pass	Pass	Pass	Pass	Pass	Pass
Distance (resmat)		Close to 0 on converged	Several trials high above 0	All close to 0	All close to 0	All close to 0	Several trials high above 0	Several trials high above 0		Several trials high above 0	Several trials high above 0	All close to 0	All close to 0	All close to 0	All close to 0	All close to 0

2.1.2 SPiCT model settings

Retrospective analysis and comparison of B/Bmsy and F/Fmsy trends suggested that models with both biomass indices (SVP and vivier index) and the long time series of landings provided better fit and diagnosis (Table 2.1, Table 2.2). Non-convergence in scenario R8 (Table 2.2) reflects the lack of information about biomass trends at the beginning of the time series of landings when only the most recent index of abundance is used. Data prior 2005 and the standardized year estimate for 2008 from the SVP biomass estimate were removed from SPiCT models, as they were considered unreliable due to limited vessel participation.

Reliability of the landings data varies across countries and throughout the time series. A precautionary approach was considered and the uncertainty was increased for the whole time series (inp$stdevfacC), but further more in the first 13 years of landings (Table 2.1). This was also to account for the missing and reconstructed Northern Irish landings prior 2002 described above.

SPiCT scenarios with no prior information for the shape of the production curve indicated an almost symmetrical shape (Table 2.1, Table 2.2; Scenarios F1, F2, R9, R10). The Schaefer production model was thus assumed and the shape of the production curve fixed (inpinilogn). Evidence and expert knowledge from the group suggested low exploitation levels before the beginning of the data used in the final model. Following SPiCT guidelines, initial depletion level was assumed to be close to carrying capacity (inp$priors$logbkfrac). Sensitivity analyses were conducted to ensure that the trends in F/FMSY and B/BMSY were relatively robust to the choice of prior.

Across SPiCT scenarios, the estimate for the intrinsic growth rate (~0.9) was considered high for a long-lived crustacean such as brown crab. Experts from the group believe this high estimate is driven by the peak in Irish landings in 2004, potentially explained by a pulse in recruitment that brought a large quantity of crabs into the fishery. Direct estimates for the intrinsic growth rate for brown crab were not found in the literature. Besides, the r values from other models might not correspond exactly to r values from SPiCT. Nevertheless, a SPiCT model carried in New Zealand rock lobster (a similar life-history species) estimated a much lower r (~0.3). The inclusion of a vague prior for r (Table 2.1,Table 2.2; Scenario G1, G2), is thus, not directly evidence driven, but based on expert knowledge about the slow growth rate of this species, particularly in the portion of the stock that is available to the fishery. The trends in B/BMSY were robust to the choice of this prior. Mean trends in F/FMSY were scaled up in the scenarios where the prior was included but within predicted confidence intervals across models. This reflects the higher vulnerability to fishing when assuming lower growth rates.

2.1.3 SPiCT outputs and caveats

SPiCT outputs indicates that the stock entered an overfished status around 2016 (Figure 2.1, Figure 2.2). Fishing mortality (F) is currently higher than optimum fishing mortality rates (Fmsy) and stock biomass (B) is below the biomass that, on average, would optimize stock productivity (Bmsy) (Figure 2.2). Stock status derived from the assessment corresponds closely with industry perception of the stock in recent years derived from questionnaire data (not shown).

The data sources and model settings described above present two main sources of uncertainty related to fishing mortality in crab stocks. These include:

(1) There may be direct transfer of crab to whelk bait in vessels that fish both species. This mortality would not be accounted for i.e. it is not seen in the landings.

(2) Significant volumes of crab have been clawed in recent years. Mortality/survival rates associated with clawing are uncertain. The assessment model presented here assumes direct mortality of clawed crabs (converted to weight by a raising factor of 5), which might over-estimate F if there is associated survival. On the other hand, it is unclear if all clawing practices are reported, and therefore seen in the landings.

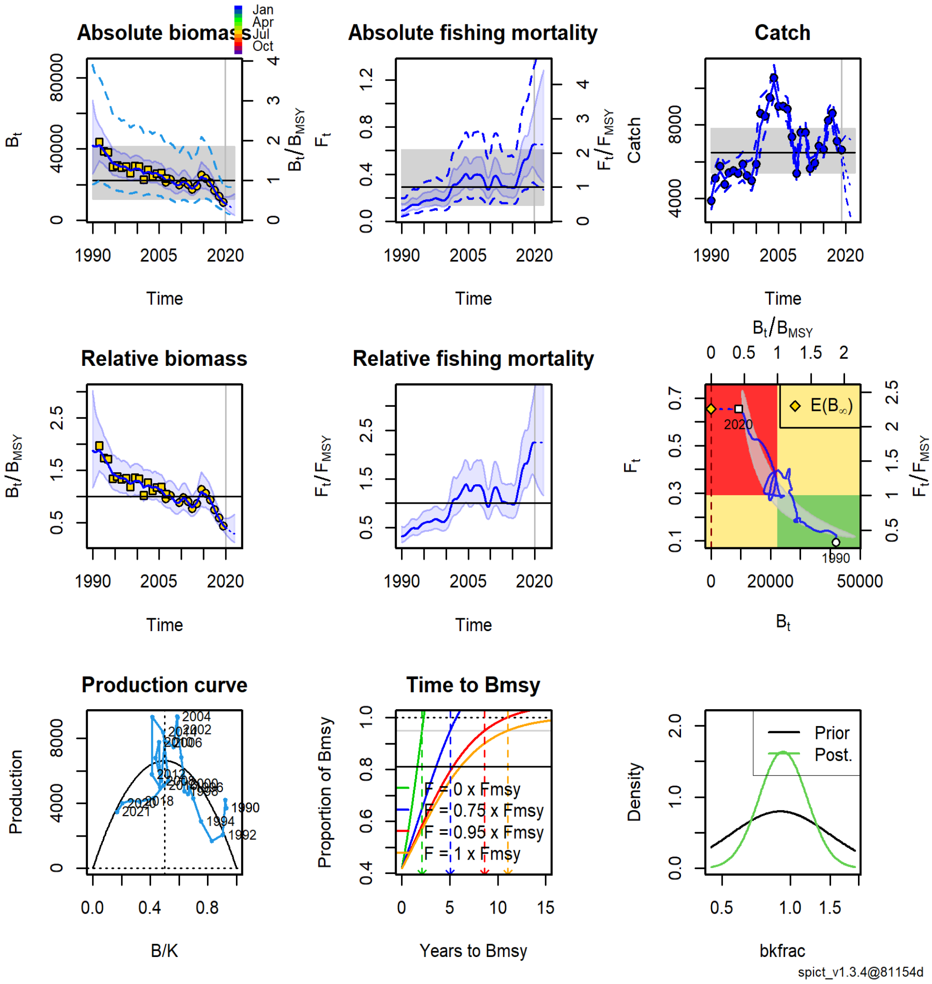


Figure 2.1. Scenario G2 SPiCT outputs.

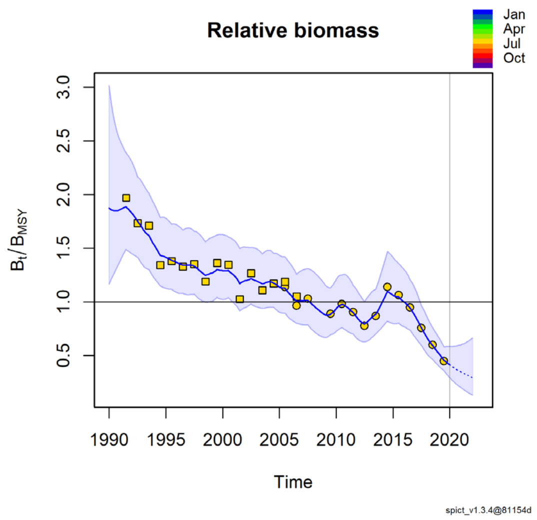


Figure 2.2: Relative biomass trends for crab in the Malin Stock

2.2 Brown crab length-based and SPiCT assessments in Scotland

2.2.1 Length-based assessments

Stock assessments based on LCAs for the period 2016-2019 were carried out for ten of the twelve assessment units (Figure 1.1), providing estimates of fishing mortality in relation to the F_{MSY} proxies (Mesquita *et al*., 2023). No assessments were performed for Mallaig as the sampling data collected were considered insufficient to run LCAs. In Shetland, fishing mortality for females were deemed inconclusive due to inconsistent results obtained when using different biological parameters estimated for Shetland and elsewhere. Of the ten assessed areas, nine were fished above the F_{MSY} proxy to some extent (Table 2.3). Fishing mortality was estimated to be above F_{MSY} for both males and females in East Coast, Hebrides, North Coast, South East, South Minch and Sule. In the Clyde, Orkney and Ullapool, fishing mortality for females was at F_{MSY} while males were fished above F_{MSY}. In Papa, recent fishing mortality was below F_{MSY}. Overall, assessment results for the period 2016-2019 showed that brown crab in most of the assessment units in Scotland were fished close to or above the F_{MSY} proxy. In many of the assessment units, a higher yield and biomass per recruit in the long term could potentially be obtained by reducing the level of fishing mortality (effort).

Table 2.3. Brown crab stock status, relationship between F and FMSY for 2006-08, 2009-12, 2013-15 and 2016-2019.

Assessment period		F (Fishing Mortality) 2006-2008	2009-2012	2013-2015	2016-19	
Clyde	Males	✗	?	✗	✗	Above F_{MSY}
	Females	✗	?	✗	O	At F_{MSY}
Hebrides	Males	✗	✓	O	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
North Coast	Males	✗	✓	✗	✗	Above F_{MSY}
	Females	✗	✓	✗	✗	Above F_{MSY}
Papa	Males	?	✓	✓	✓	Below F_{MSY}
	Females	?	✓	O	✓	Below F_{MSY}
Shetland	Males	?	?	✗	?	Unknown
	Females	?	?	?	?	Unknown
Sule	Males	✗	O	✗	✗	Above F_{MSY}
	Females	O	✗	✗	✗	Above F_{MSY}
East Coast	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
Mallaig	Males	?	?	?	?	Unknown
	Females	?	?	?	?	Unknown
Orkney	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	O	At F_{MSY}
South East	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
South Minch	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
Ullapool	Males	?	?	?	✗	Above F_{MSY}
	Females	?	?	?	O	At F_{MSY}

2.2.2 SPiCT assessment

For most data-limited fisheries, surplus production models are used to assess stocks' biomass and exploitation level where age and size data are unavailable (Punt, 2003). These models do not require information regarding stocks' age and size structures. Therefore, surplus production models are mainly applied to stocks where commercial catches and indexes such as catch-per-unit effort (CPUE) are the only data available (Polacheck *et al*., 1993).

For over a decade now, Brown crab assessments in Scotland have been carried out using the Length Cohort Analysis (LCA) methodology (Mesquita *et al.*, 2023). This method mainly uses length frequency data. However, commercial catches and an index of exploitable biomass derived from scientific survey data have become available for brown crab on the West and East Coast of Scotland (Mesquita *et al.*, 2021). This report section describes a preliminary assessment of Brown crab in these areas using the Surplus Production Model in Continuous Time (SPiCT) (Pedersen and Berg, 2017).

Assessment areas and data

The assessment was run for the brown crab in two areas: the east and west coast of Scotland. These areas so not coincide with the management units for crabs and lobster in Scotland (Figure 1.1) but were selected based on the data available for the Scottish dredge and trawl surveys which were used to derive abundance indices (Mesquita *et al.*, 2021). In both areas, although commercial landings data are available from 1974 – 2021, it is difficult to establish how accurate the pre-2006 data were, as landings then were believed to have been underreported before the introduction of the 'buyers and sellers' legislation. Therefore, only commercial landings data from 2008 onward were used in the SPiCT assessment, as they are perceived to be more reliable.

The abundance indices used in the assessment was estimated for both regions from fishery independent data. In this assessment, the following indices were used: For the East Coast, abundance index from the dredge and trawl survey were available from 2008 – 2019 and 2008 – 2020, respectively (Figure 2.3). For the West Coast, the abundance index from the dredge and trawl were available from 2008 – 2019 and 2011 – 2020, respectively (Figure 2.4). The methodology used for the standardization of these indexes used is documented by Mesquita *et al.*, 2021.

Assessment configurations

The Surplus Production Model in Continuous Time (SPICT) is based on the generalized surplus production model. More detailed information about the SPiCT model can be found in Pedersen and Berg (2017). In this preliminary assessment, several scenarios including the SPiCT default were explored for both regions before narrowing to only two scenarios that converged. Hence, the settings used for the two different scenarios for each area (the east and west coast) were as follows:

- In scenario 1 - the surplus production curve was fixed to be symmetrical. Also, priors were added for the initial biomass depletion.
- Scenario 2 settings were the same as for 1, but an extra uncertainty term was added to the first 5 years of the landings. For more detail information on SPiCT model settings see: https://github.com/DTUAqua/spict

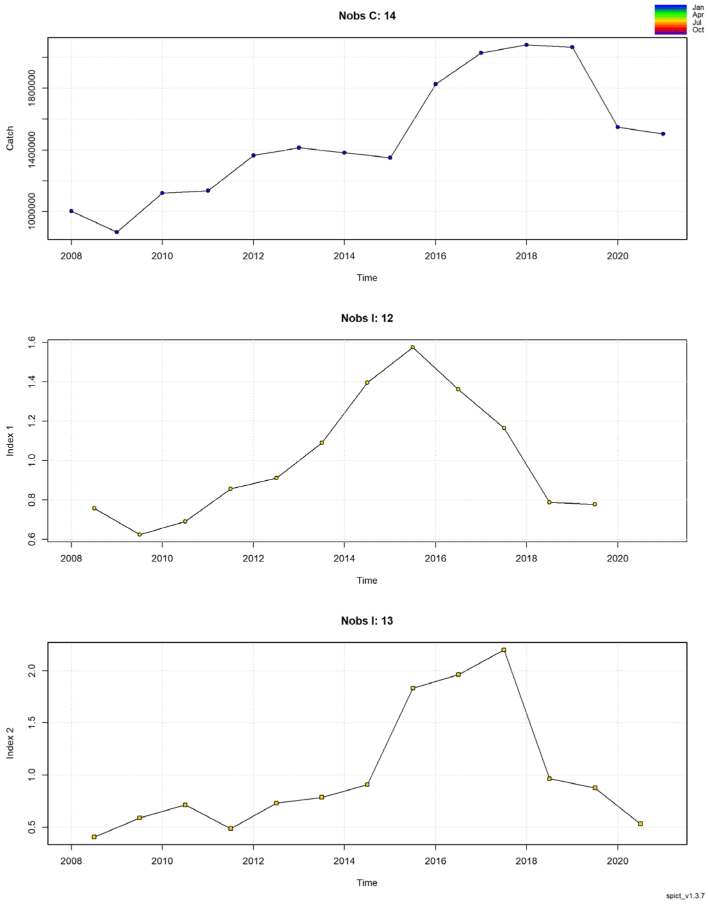


Figure 2.3. East coast input data showing the catch and survey indices time series used. Indices 1 and 2 are the standardized and estimated from the dredge and trawl surveys respectively.

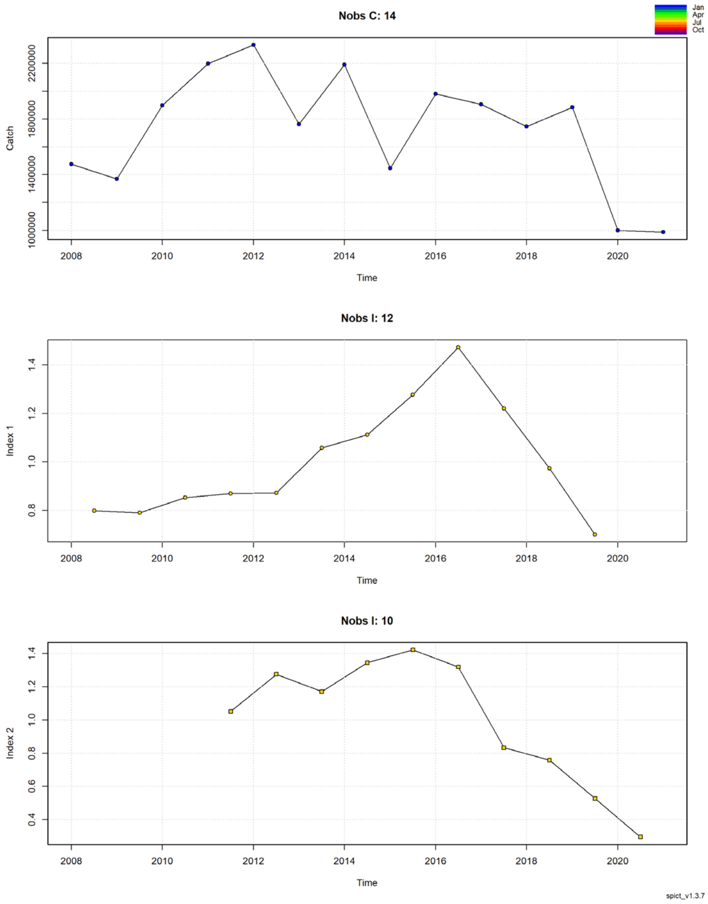


Figure 2.4. West coast input data showing the catch and survey indices time series used. Indices 1 and 2 are the standardized and estimated from the dredge and trawl surveys respectively.

Model diagnosis

In the two scenarios for both areas, model diagnostic suggests that all assumptions were not violated; and the AIC from the model were as follows:

Area	Scenario 1	Scenario 2
East Coast	39.22	38.86
West Coast	33.27	30.93

Results and discussion

Although all model assumptions were met for both areas, diagnosis plots suggest scenario 2 to be the most parsimonious. Also, in both areas, retrospective analysis and comparison of B/B_{MSY} and F/F_{MSY} trends suggest a better fit and diagnosis for scenario 2 (Figure 2.7 and Figure 2.8). Hence, only the output for this scenario has been presented in this report.

Assessment outputs suggest that brown crab from Scotland's east and west coast are currently fished above reference points (Figure 2.5 and Figure 2.6). For the east coast, the result suggests that there has been a steady decline in the stock biomass of brown crab since 2016. The fishing mortality for this species is currently above the optimum fishing mortality rate ($F>F_{MSY}$); also, the current stock biomass (B) is below the biomass that would have optimized stock productivity (B_{MSY}). On the west coast, although the uncertainty around the reference point is high (Figure 2.6, grey boxes), the confidence intervals are narrower for the relative values of F and B. Again, the current fishing mortality (F) is higher than FMSY, and stock biomass is below BMSY. The preliminary SPiCT assessment results for both areas support a decrease in stock biomass (in line with the recent landings trend) and an increase in fishing mortality. The outputs of the model applied to the Scottish data were similar to those presented for brown crab in Ireland, also using SPiCT.

There are a few caveats, which might influence the output of this analysis. Firstly, both indices data used were shorter than the available landings data. Furthermore, the two indices used on the west coast had different trends; this could be problematic for the model since they were both observed at the same point in the year. Therefore, it would be beneficial to keep updating this analysis as the landings and indices time series keep expanding.

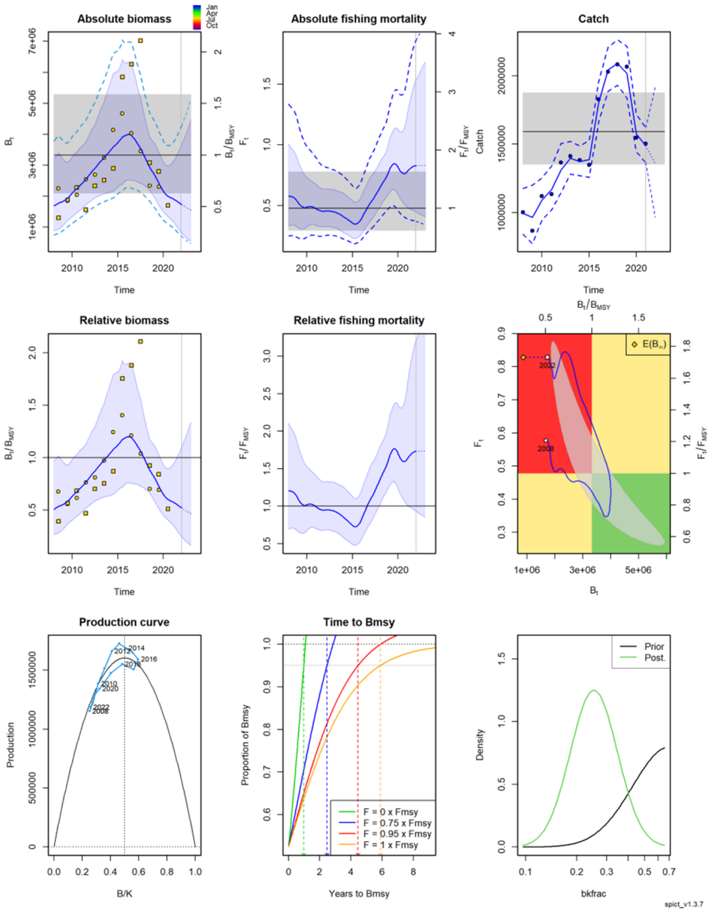


Figure 2.5. East Coast SPiCT model output showing estimates of biomass, fishing mortality, catch, and production curve. 95% CIs of absolute quantities are shown using dashed blue lines. While 95% CIs of relative biomass and fishing mortality are shown using shaded blue regions. Estimates of reference points (B_{MSY}, F_{MSY}, MSY) are shown using black lines, with grey shaded region representing showing the 95% CIs of the reference points. The vertical grey line represents the end of the data range, while predictions beyond the data range are shown using the dotted blue lines.

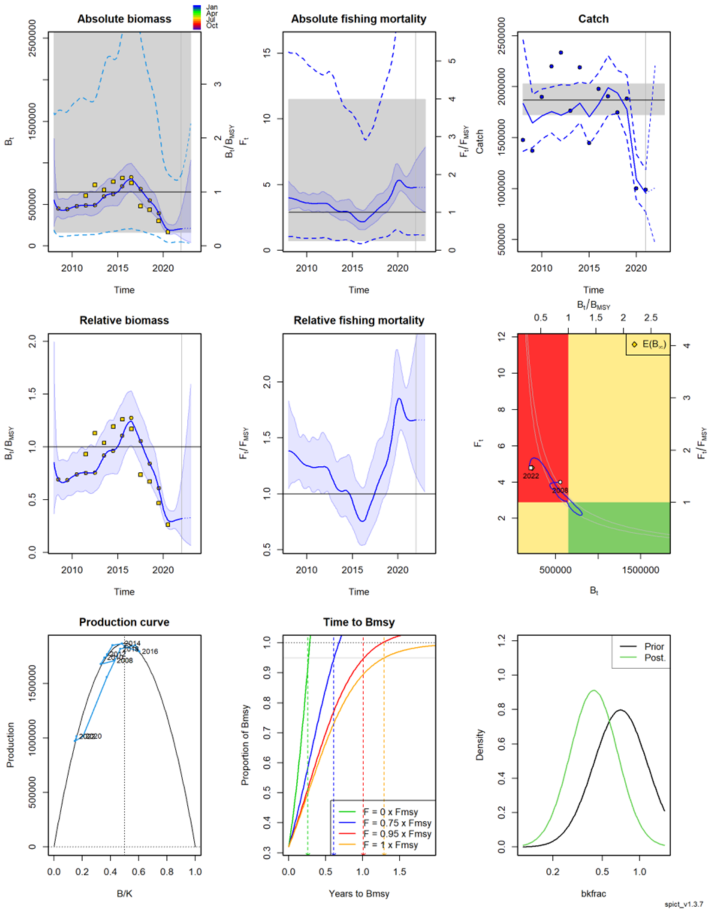


Figure 2.6. West Coast SPiCT model output showing estimates of biomass, fishing mortality, catch, and production curve. 95% CIs of absolute quantities are shown using dashed blue lines. While 95% CIs of relative biomass and fishing mortality are shown using shaded blue regions. Estimates of reference points (BMSY, FMSY, MSY) are shown using black lines, with grey shaded region representing showing the 95% CIs of the reference points. The vertical grey line represents the end of the data range, while predictions beyond the data range are shown using the dotted blue lines.

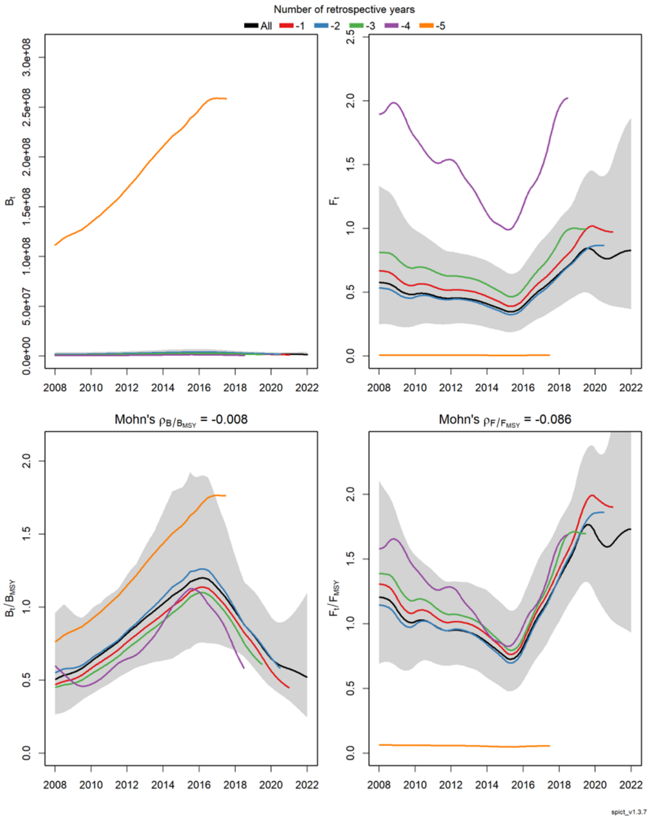


Figure 2.7. Plot showing 5 retrospective years for absolute biomass and fishing mortality (top row) and relative biomass and fishing mortality (bottom row) for the East coast.

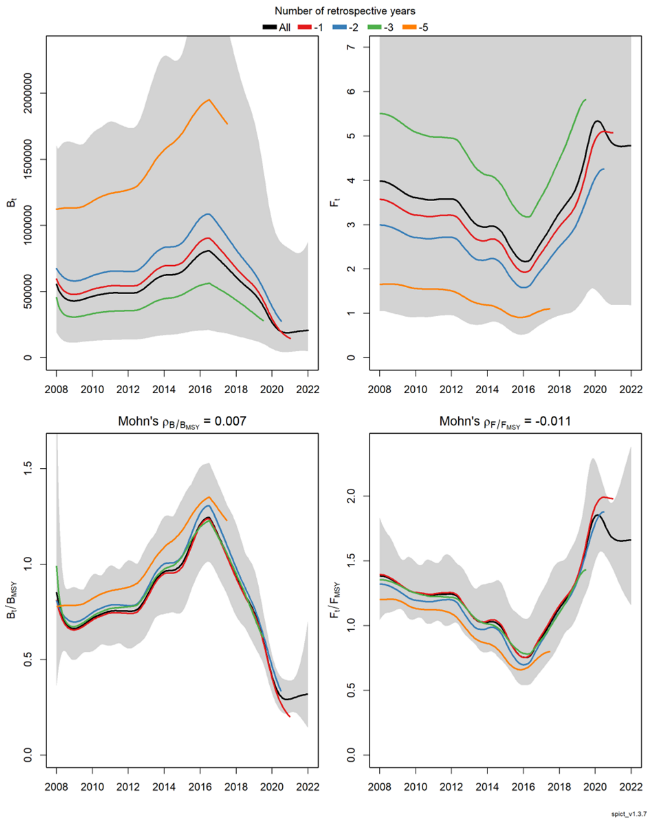


Figure 2.8. Plot showing 5 retrospective years for absolute biomass and fishing mortality (top row) and relative biomass and fishing mortality (bottom row) for the West coast.

2.3 Joint Stock Assessment (England/France) for brown crab in the Western Channel

2.3.1 Western Channel

Brown crab *Cancer pagurus* are fished widely around the English and French coasts. The fisheries are important to both countries both socially and economically, and are comprised of large off-shore vessels that fish in the mid-Channel as well as smaller inshore vessels on both sides of the Channel. French vessels are permitted to fish up to 6 nautical miles off the English coast and English vessels can fish up to 12nm off the French coast. They are predominantly trap fisheries with a small bycatch from trawlers and gillnetters. Management are mostly technical measures with a minimum landing size of 140-160mm carapace width. There is known movement of crabs between French and English fishing grounds in the Channel, and crabs, particularly females, are known to travel long distances.

In 2021, an ICES data call was requested by WGCRAB to develop the first integrated length-based stock assessments in the English Channel for brown crab. All ICES member countries that participate in the *C. pagurus* fisheries in the English Channel were requested to submit length frequency data, annual landings disaggregated by month, biological data, and effort data by ICES statistical rectangle from 2014 to 2020. Length data from landings into England and France in the Western Channel were analyzed (Figure 2.9) and a length-based virtual population analysis was carried out with data from 2014-2019.

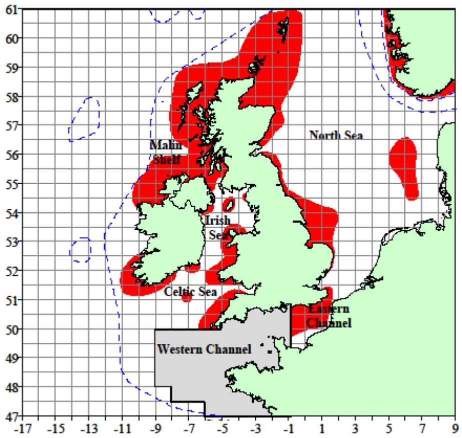


Figure 2.9. Western Channel crab stock assessment region.

Length samples were taken from crabs caught in the Western Channel and landed into England and France. These were raised step-wise using official landings data to provide annual length distributions by sex. Number of animals sampled was higher for English compared to French data relative to national landings (Table 1), causing the assessment to be influenced more by English data. Landings are higher from the Western Channel into England than into France, and there is a similar declining trend in both countries (Figure 2.10).

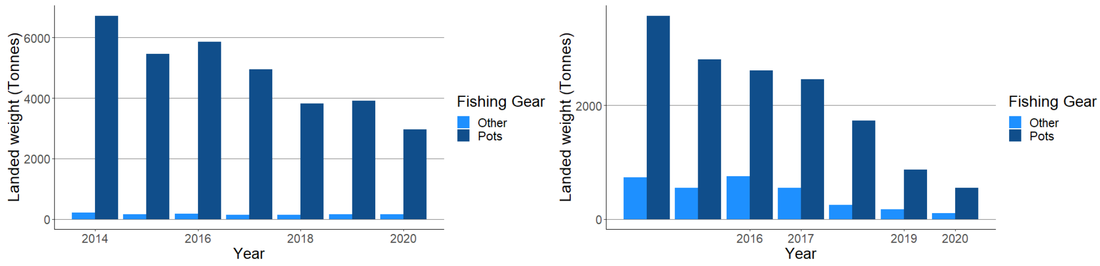


Figure 2.10. Annual landings into England (left) and France (right) from the Western Channel

Table 2.4. Number of crabs sampled per year by Cefas (England) and Ifremer (France).

	Cefas	Ifremer	Total
2014	6,694	1,233	7,927
2015	8,240	2,231	10,471
2016	7,661	1,029	8,690
2017	6,951	1,705	8,656
2018	7,689	2,600	10,289
2019	8,431	1,398	9,829
2020	3,922	479	4,401

Within the assessment model, natural mortality is assumed to be 0.2. Other fixed parameters which have been taken from the literature and available data are growth rate, maximum size, fecundity and maturity. Assessment outputs are averaged over three years to reduce noise in the data. An MSY proxy of 35% spawner per recruit is used as a target level, with a limit of 15% spawner per recruit. Outputs presented are average fishing mortality at length (Figure 2.11) and spawning stock biomass (Figure 2.12).

Fishing mortality for females has declined from 2017-2019 but is close to the F_{MSY} target. Exploitation for males is below the target level. The English fishery in the Western Channel is predominantly a female fishery as landings for males are very low, so estimates for males are less reliable. Spawning biomass has declined for males and females since 2014. Biomass for females is within the MSY target and limit reference levels from 2017-2019.

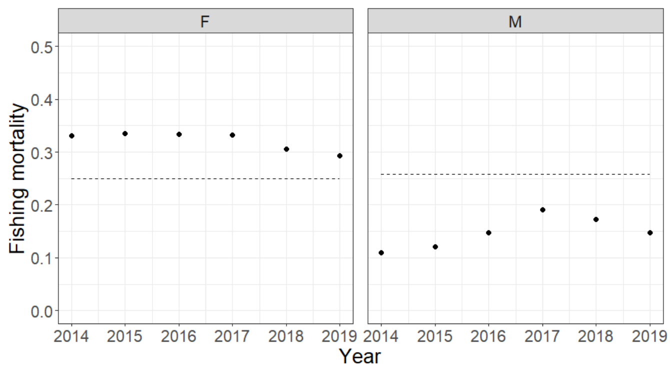


Figure 2.11. Estimated fishing mortality time series for males and females. Dashed line = F_{MSY} target.

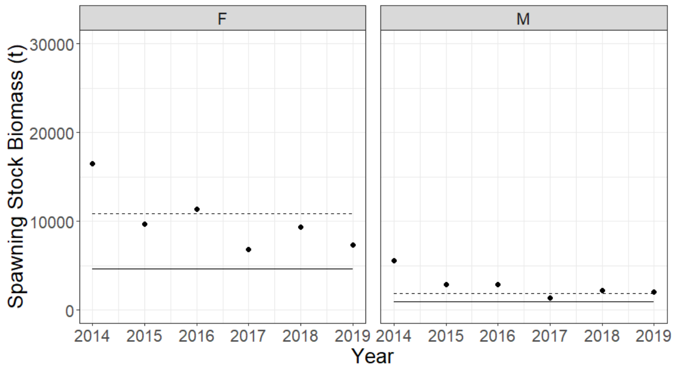


Figure 2.12. Biomass time series with MSY target (dashed) and minimum reference point limit (solid).

Biomass estimates reflect the annual landings of crabs, whilst estimates of exploitation are sensitive to changes in length distributions. Given the lower level of landings and sample numbers from the French fishery, the assessment outputs are more similar to the assessment for the English Western Channel fishery. Similar trends of a decrease in landings are evident on both sides of the Channel, although it is more pronounced in the French landings data, particularly in the most recent three years. The trend decrease has continued in 2022 and at the time this report was finalised, the vivier offshore potters were not operating in the French side for economic reasons linked to low catches.

2.3.2 Length-based assessments in England

Length-based assessments were carried out to assess the stock status of brown crab in the Central North Sea, Southern North Sea, Western Channel and Celtic Sea. Data were insufficient for an assessment in the Eastern Channel, and assessments were only done for females in the Western Channel and Celtic Sea, which are female-dominated fisheries. Landings, effort, fishing mortality and spawning stock biomass were presented, with 15% virgin spawner per recruit and 35% spawner per recruit as an MSY proxy limit and target respectively. Exploitation in the Central North Sea is moderate and stable, and landings are increasing. The Southern North Sea has a high but stable exploitation rate, with fishing mortality above the limit, although landings and biomass are increasing. Exploitation rates are moderate and stable in the Western Channel and Celtic Sea, although landings and biomass are declining in the Western Channel and are stable in the Celtic Sea. As expected, this is in agreement with the combined England/France assessment presented in Section 2.3.1. An alternative assessment model incorporating migration from tagging data in the Channel is being developed. Net migration occurs from east to west. Preliminary results show the same trends for fishing mortality, although absolute values are different.

2.4 Brown crab length-based indicators in Northern Ireland

For brown crab in Northern Ireland, the length at which growth is maximum, L_{opt}, is used as a proxy for MSY. Length data is collected through the AFBI observer programme, which has been collecting data onboard commercial fishing vessels since 2010 (no data is available in 2020 due to Covid-19 which meant observer trips could not take place). For the assessment, males and females are split. The assessment also does not include animals from Strangford Lough which are believed to have a faster growth rate. Using data up to 2021, the output of the assessment indicates that currently both male and female brown crabs are shown to be overexploited (mean length is below L_{opt}). Over the assessment years, the mean size of male brown crab has never been above L_{opt}, whilst the mean size of female brown crabs has only been above L_{opt} in 2015 (Figure 2.13).

A commercial LPUE time series is used to indicate stock trends, based on the ICES category 3 assessment method. AFBI provide annual advice on the inshore stocks in NI. For brown crab the advice is based on the ratio of the mean of the last two index values (Index A) and the mean of the three preceding values (Index B), multiplied by the recent average catch. If the mean size of animals has been shown to be below L_{opt}, a precautionary buffer of -20% is included in the calculation. The advice for brown crab in 2022 suggests that there should be a 50% reduction in landings (Table 2.5).

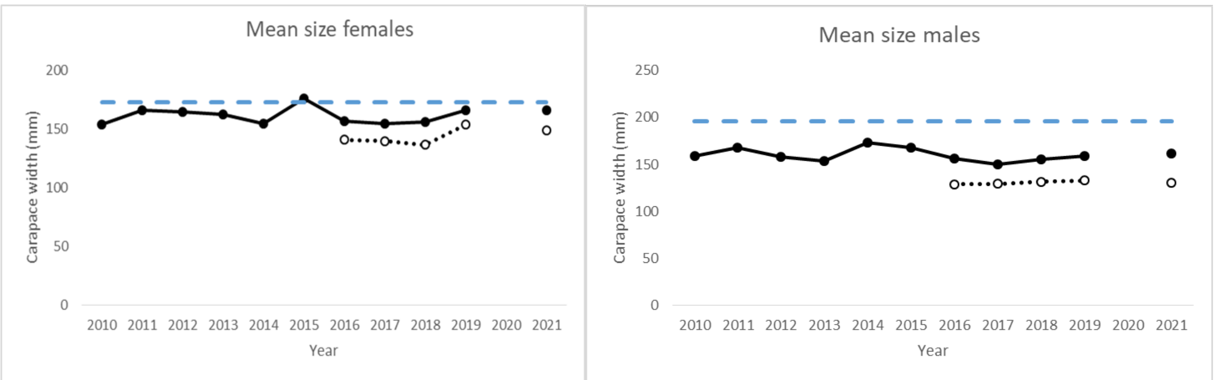


Figure 2.13. Length-based indicator for male and female brown crab from Northern Ireland waters. The solid black line indicates mean size crab landed and the dashed black line is mean size of all crab measured. The dashed blue line indicates L_{opt}.

Table 2.5. Brown crab in ICES rectangles: 37E3, 37E4, 38E4, 39E3, 39E4. Basis for advice.*

Index A (2020 - 2021)	1.53 kg/pot
Index B (2017–2019)	2.47 kg/pot
Index ratio (A/B)	0.62
Recent landings for 2018 – 2021**	768 t
Precautionary Reduction	Applied (0.8)
Landings advice***	381 t
% Advice change ^	-50.4 %

*** The figures in the table are rounded. Calculations were done with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.**

**** 2020 landings excluded due to Covid-19 impacts on landings**

***** [Mean recent landings (2018 – 2021)] × [Index Ratio].**

^Advice change is based on the current advised landings compared to mean recent landings (2018 – 2021). No cap in advice change applied.

2.5 Exploratory brown crab assessments in Norway

As a part of a MSc thesis in collaboration with IMR (Marcussen, 2022), three assessment methods suggested by ICES were tested: (i) Length-Based Spawning Potential Ratio (LBPR; (Hordyk *et al*., 2016)), (ii) Length-Based Indicators, and (iii) Surplus Production Models in Continuous Time (SPiCT; (Pedersen and Berg, 2017)). Although brown crab in Norway is not extremely data poor and has a relatively long (>20 years) time series, LBSPR and SPiCT performed poorly and were not accepted. This highlights the data-limited methods' specific demands for data quantity and quality. Formal assessment of data-limited stocks requires explicit adjustment to available methods, plenty of assumptions, and reliable biological inputs. As a result, the simplest methods are often the ones performing best when biological input data are uncertain and key assumptions of more advanced methods are violated (Cousido-Rocha *et al*., 2022). The simplest method applied here, LBI, indicated stable trends with a mean length below target levels, except for both sexes in Midt-Norge and males in Helgeland (Figure 2.14). Furthermore, it showed that all the areas were below the target for the 5 % largest, and the absence of the largest individuals in the catches, implies a length truncation, a known signal of accumulated fishing mortality (Miethe and Dobby, 2015). However, this is not in line with the knowledge of the fishery that suggests relevant fishing pressure but no overfishing. The method's sensitivity for the input value, the asymptotic width, was tested and supports the concern of high sensitivity towards the input values. Life-history parameters for this study were largely based on literature values from other regions. The results emphasize therefore the need for region-specific knowledge of the biological data of the brown crab.

The main reasons explaining why the two other methods performed poorly are believed to be: 1) the general lack of contrast in the data challenges the use of the index in surplus production models for stock assessment; 2) the violation of the assumption of logistic selectivity in the LBSPR methods and the lack of options to adjust the LBSPR to the features of the fishery (dome-shaped selectivity); 3) large unreported catches in the fishery because of substantial recreational fishing and bycatches in other fisheries. It was concluded that using the index directly combined with length-based indicators might, thus, be the most adequate option available to date to assess qualitative trends in stock status. The goal remains, however, to establish an analytical stock assessment framework for the Norwegian stock of brown crab and provide advice. Several challenges need to be overcome to achieve this, most notably to quantify the unreported catches to produce a time series of total estimated removals. However, recreational landings are not registered and knowledge about other sources of mortality such as bycatch, discard, ghost fishing, etc. is limited. Furthermore, it is currently unclear how CPUE/LPUE indices based on passive gear, like pots, relate to changes in abundance and whether the link is nonlinear because of potential hyperstability of the catches.

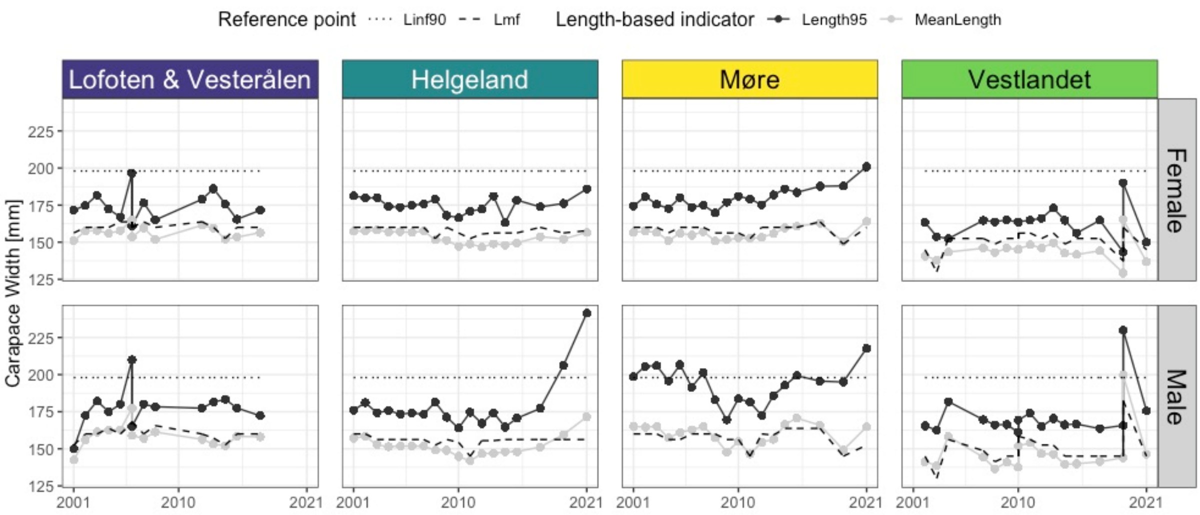


Figure 2.14. Length-based indicators. Annual changes in the size structures, expressed through the length-based indicators for each of the assessment units and for both sexes. The indicators mean width (grey) and mean width of the 5% largest individuals (black), and their respective reference points, Lmf (dashed line) and Linf90 (striped line). Lm=F refers to the mean width when natural mortality equals fishing mortality and Linf90 refers to 90% of the asymptotic width.

2.6 Newfoundland & Labrador snow crab - Toward a Cohort Population Model

The NL snow crab stock has consistently been the world's largest for decades, but unlike other major global snow crab stocks it lacks a formalized population model for stock assessment. This outcome is affected by a diverse data collection system featuring different gear types (trawls, large mesh traps, small mesh traps) used in different stock regions at different times of the year to monitor the resource and associated poor understanding of selectivity and catchability influences on stock size measurements. Moreover, size-at-age dynamics are poorly understood, and recent work shows considerable but spatially and annually variable levels of skip-molting in males, which complicates the ability to apply stage-based transition models.

Figure 2.15 (left panel) shows raw Campelen trawl catch distributions of male and female snow crab among different divisions of the NL shelf and in different seasons in relation to an exponential decay mortality curve (Z). Figure 2.15 (right panel) shows a logistic (size-based) selectivity curve applied to adjust abundance estimates. The improved mortality curve on the right panel fits better than and this implies an order of magnitude difference in y-axis scale in comparison with the graph in left panel (without the logistic selectivity curve). This analysis highlights how application of results from a suite of research on gear selectivites in different environments within the expansive stock range, used in exploratory analysis of instar-based stages of relative abundance, are able to coarsely capture signals of exploitable biomass occurring in the population. The analysis establishes that a stage-based transition model is likely possible, but that research needs to be conducted to understand factors affecting growth transition rates, and highlights most plausible factors affecting growth and mortality that need to be understood to reliably employ a transition model for assessment of this resource.

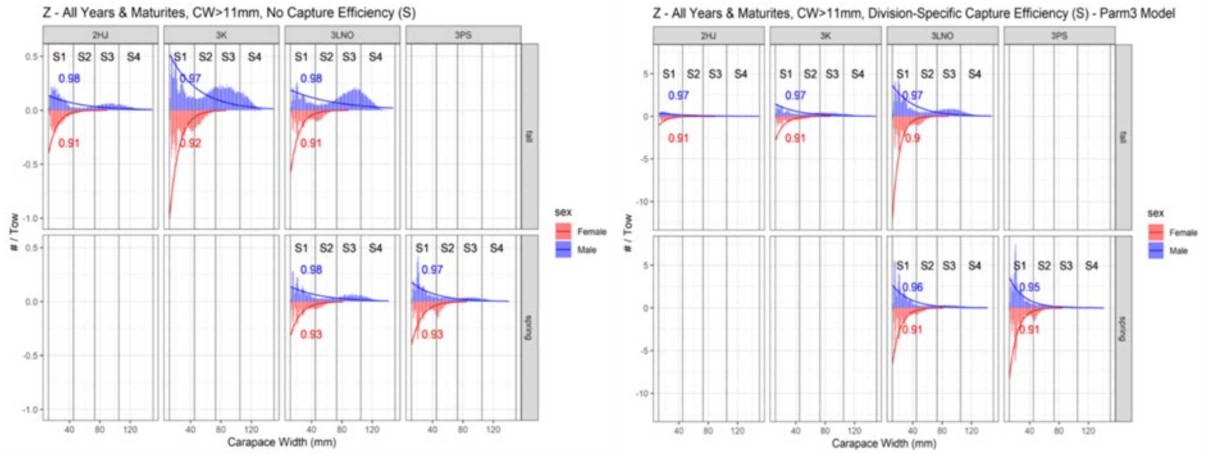


Figure 2.15. Left panel: raw Campelen trawl catch distributions of male and female snow crab among different divisions of the NL. Right panel: Campelen trawl catch distributions of male and female snow crab with a logistic (size-based) selectivity curve applied to adjust abundance estimates, producing a better model fit. Alpha-numerics (S1, etc.) show size stages conforming to different groupings of instars identified for future research on different process affecting growth and mortality rates in the population.

2.7 European lobster length-based assessment in Scotland

Stock assessments based on LCAs for the period 2016-2019 were carried out for eight of the twelve assessment units (Figure 1.1), providing estimates of fishing mortality in relation to the F_{MSY} proxies (Table 2.6) (Mesquita *et al*., 2023). Sampling data were considered to be insufficient (low numbers and infrequent sampling) for running assessments in Mallaig, North Coast, Sule and Ullapool. Lobsters in all the assessed areas were fished above the F_{MSY} proxy to some extent, particularly males. Fishing mortality was estimated to be above F_{MSY} for both males and females in Clyde, South East, Shetland and South Minch. In the East Coast, Hebrides, Orkney and Papa, fishing mortality for females was at F_{MSY} or below while males were fished above F_{MSY}. Overall, assessment results for the period 2016-2019 show that lobster in most of the assessment units in Scotland were fished close to or above the F_{MSY} proxy. A higher yield and biomass per recruit in the long term could potentially be obtained in all assessment units by reducing the level of fishing mortality (effort).

Table 2.6. Lobster stock status, relationship between F and F_{MSY} for 2006-08, 2009-12, 2013-15 and 2016-2019.

Assessment period		F (Fishing Mortality)				
		2006-2008	2009-2012	2013-2015	2016-19	
Clyde	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
Hebrides	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✓	✓	✓	✓	Below F_{MSY}
North Coast	Males	✗	?	?	?	Unknown
	Females	✓	?	?	?	Unknown
Papa	Males	?	✗	✗	✗	Above F_{MSY}
	Females	?	✓	✓	✓	Below F_{MSY}
Shetland	Males	?	✓	✗	✗	Above F_{MSY}
	Females	?	✗	✗	✗	Above F_{MSY}
Sule	Males	?	?	?	?	Unknown
	Females	?	?	?	?	Unknown

Assessment period		F (Fishing Mortality)				
		2006-2008	2009-2012	2013-2015	2016-19	
East Coast	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	O	At F_{MSY}
Mallaig	Males	?	?	?	?	Unknown
	Females	?	?	?	?	Unknown
Orkney	Males	✗	✗	✗	✗	Above F_{MSY}
	Females	✓	O	O	✓	Below F_{MSY}
South East	Males	✓	✗	✗	✗	Above F_{MSY}
	Females	✗	✗	✗	✗	Above F_{MSY}
South Minch	Males	?	✗	✗	✗	Above F_{MSY}
	Females	?	✗	✗	✗	Above F_{MSY}
Ullapool	Males	✗	?	?	?	Unknown
	Females	✓	?	?	?	Unknown

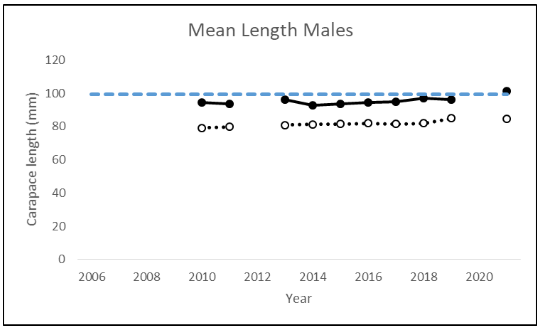
2.8 European lobster length-based assessment in England

Length-based stock assessments were carried out for European lobster in 2019 and presented to the WGCRAB group in 2020. Assessments were available for the following regions: Northumberland and Durham; Yorkshire Humber; East Anglia; Southeast South Coast; Southwest. Exploitation rate is high in Northumberland, Yorkshire and East Anglia, and medium in the Southeast and Southwest. Fishing mortality is declining and biomass increasing in Northumberland. Elsewhere the fisheries are stable, apart from a decline in fishing mortality and landings in the Southeast.

2.9 European lobster length-based indicators in Northern Ireland

For lobster in Northern Ireland, the length at which growth is maximum, L_{opt}, is used as a proxy for MSY. Length data is collected through the AFBI observer programme, which has been collecting data onboard commercial fishing vessels since 2010 (no data is available in 2020 due to Covid-19 which meant observer trips could not take place). For the assessment males and females are split. The assessment also does not include animals from Strangford Lough which are believed to have a faster growth rate. Whilst usually only landed animals are used in this type of assessment, for lobsters, as many animals greater than the MLS are v-notched through the industry scheme, all lobsters 87mm+ have been included in the analysis, regardless of if they were landed or discarded. Using data up to 2021, the output of the assessment indicates that currently both male and female lobsters are at a mean length above L_{opt}. Whilst female lobsters have consistently been above L_{opt} (Figure 2.16), perhaps due to the level of v-notching carried out in Northern Ireland waters, 2021 is the first year that mean length of male lobsters have been above L_{opt}.

A commercial LPUE time series is used to indicate stock trends, based on the ICES category 3 assessment method. AFBI provide annual advice on the inshore stocks in NI. For lobsters, the advice is based on the ratio of the mean of the last two index values (Index A) and the mean of the three preceding values (Index B), multiplied by the recent average catch. If the mean size of animals has been shown to be below L_{opt}, a precautionary buffer of -20% is added. The advice for lobster for 2022 suggests that there may be a small increase in lobster landings (Table 2.7).



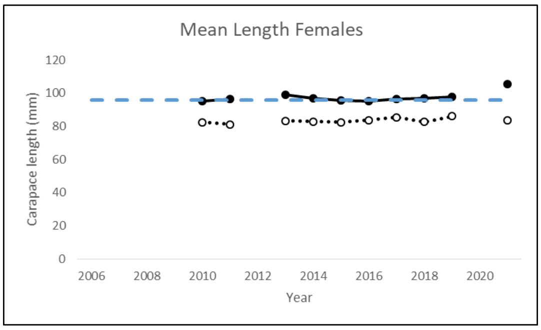


Figure 2.16. Length-based indicator for male and female lobsters from Northern Ireland waters. The solid black line indicates mean size lobster landed and the dashed black line is mean size of all lobsters measured. The dashed blue line indicates L_{opt}.

Table 2.7. Lobster in ICES rectangles: 37E3, 37E4, 38E4, 39E3, 39E4. Basis for advice.*

Index A (2020 - 2021)	0.39 kg/pot
Index B (2017–2019)	0.38 kg/pot
Index ratio (A/B)	1.02
Recent landings for 2018 – 2021**	63 t
Precautionary Reduction	Not applied
Landings advice***	64 t
% Advice change ^	+1.7 %

*** The figures in the table are rounded. Calculations were done with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.**

**** 2020 landings excluded due to Covid-19 impacts on landings**

***** [Mean recent landings (2018 – 2021)] × [Index Ratio].**

^Advice change is based on the current advised landings compared to mean recent landings (2018 – 2021). No cap in advice change applied.

2.10 European lobster surplus production analysis in Jersey

A surplus production analysis (SPiCT) on the joint lobster stock for the 2019 MSC audit suggested that Jersey stocks had been exploited at levels considerably above MSY between 2011 and 2017 impacting the stock biomass. It was noted from the analysis that the annual catch had been below MSY since 2018 although, in the view of Jersey, this is not a reflection of improving stock health but of a stock issue as indications from this assessment and other monitoring data suggest that the relative biomass is also declining. In 2021, Jersey performed a surplus production analysis (CMSY) on the commercial lobster dataset (Figure 2.17). The results were similar to the SPiCT analysis of 2019 and suggested that a sustained period of fishing above MSY between 2010 and 2017 had been followed by a sharp decline in annual landings and a decline in stock size to a B/Bmsy level of 0.78 against a target of 1.0. In addition to this, the quayside lobster measurements collected since 2018 were used to perform a length-based Virtual Population Analysis (VPA). The results, which are currently tentative, reinforce the general conclusions of the SPiCT and CMSY analyses, suggesting that while the current catch weight is below MSY, the spawning stock biomass is below the 35% threshold indicative of a healthy stock but above the lower limit of 15% SSB.

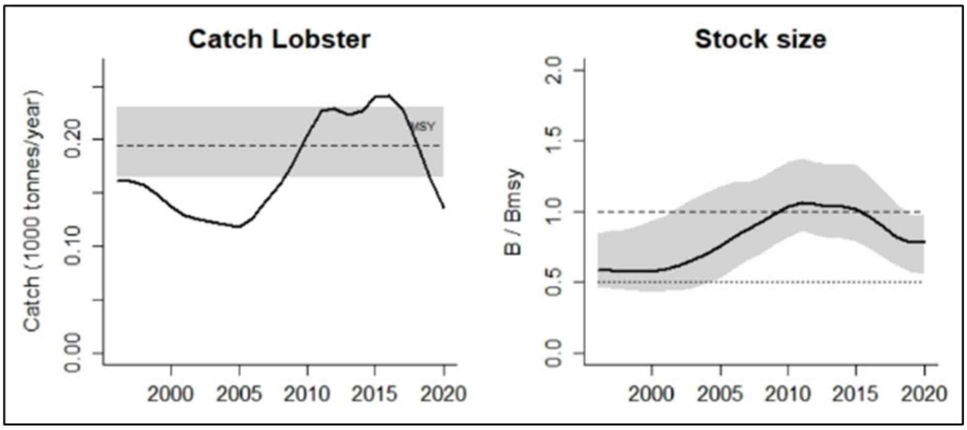


Figure 2.17. The results of a surplus production analysis (CMSY) for lobster based on Jersey commercial landings between 1996 and 2020.

2.11 Analysis of size indicators for European lobster in Wales

A dataset consisting of carapace length data from 1983 -2021 was compiled. This was obtained from the iFish database of port sampling and historical sea fisheries committee port sampling data. A preliminary analysis was undertaken of these data utilising size-based indicators. Due to interannual variation in where and when sampling took place and the amount of data in each year, a rolling average approach was taken. A 10-year rolling average was chosen to approximate a generation time. Each "window" had a minimum of 7 years' worth of data and a minimum of 1387 measurements (mean 4468).

The following size metrics were calculated for each time "window": Mean size (L_{mean}), 25^{TH} percentile size ($L_{25\%}$) and mean size of the largest 5% ($L_{max5\%}$). These were plotted (x-axis showing the last year in the "window") and a loess smoother used to visualise the trend over time. Size based indicators require life history traits to create reference points. For Welsh lobsters, there are no existing growth data or estimates of L_{inf}, however some maturity estimates were available. This has allowed the estimation of reference points for the following indicators using work carried out by ICES WKLIFE (ICES, 2012; ICES, 2018) and others (Froese and Sampang, 2012; Froese and Sampang, 2013):

Indicator	Description	Limit reference point	Target reference point
L_{mat}	The mean length in the catch over a period of ~ a generation should be greater than the size at maturity.	L_{mean}/L_{50} >1	L_{mean}/L_{90} >1 Or $L_{mean}/1.2*L_{50}$ >1
$L_{25\%}$	The 25TH percentile in the landed catch size distribution over a period of ~ a generation should be larger than size at maturity.	$L_{25\%}/L_{50}$ >1	$L_{25\%}/L_{90}$ >1 Or $L_{25\%}/1.2*L_{50}$ >1

In south Wales, the mean size of both sexes decreased during the early part of the time series before starting to increase from 2000 – 2021. In north Wales, the mean size of both sexes in the catch was fairly stable in the early part of the time series, but increased from approximately 2010 onwards (Figure 2.18). Females in south Wales have shown a decline in the $L_{max5\%}$ from the start of the time series to approximately 2012, after which there has been some increase. Males showed a more rapid decline in the early part of the time series, a stable period before increasing again from around 2012. In north Wales, both Males and female showed a decline from the start of the time series to approximately 2010, both showed a temporary increase around 2002, this was much more pronounced for Males (Figure 2.19). Both sexes have shown rapid increases since 2012. The mean size indicator has increased slightly for over time and lies between the limit and target reference points. The 25TH percentile indicator has increased slightly over time and has been at or below the limit reference point.

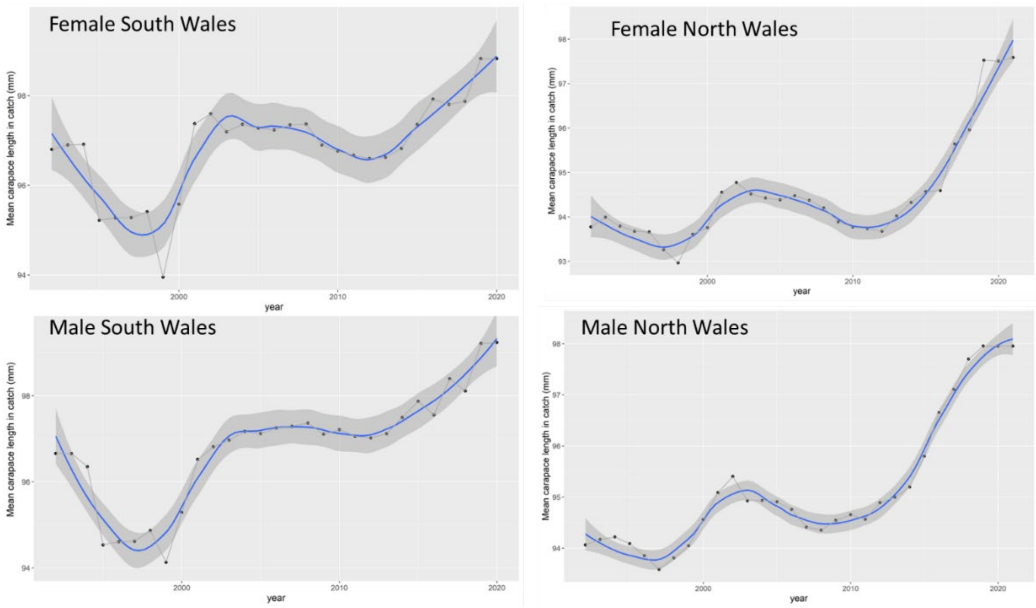


Figure 2.18 .Rolling 10-year average mean carapace length for lobster in Wales

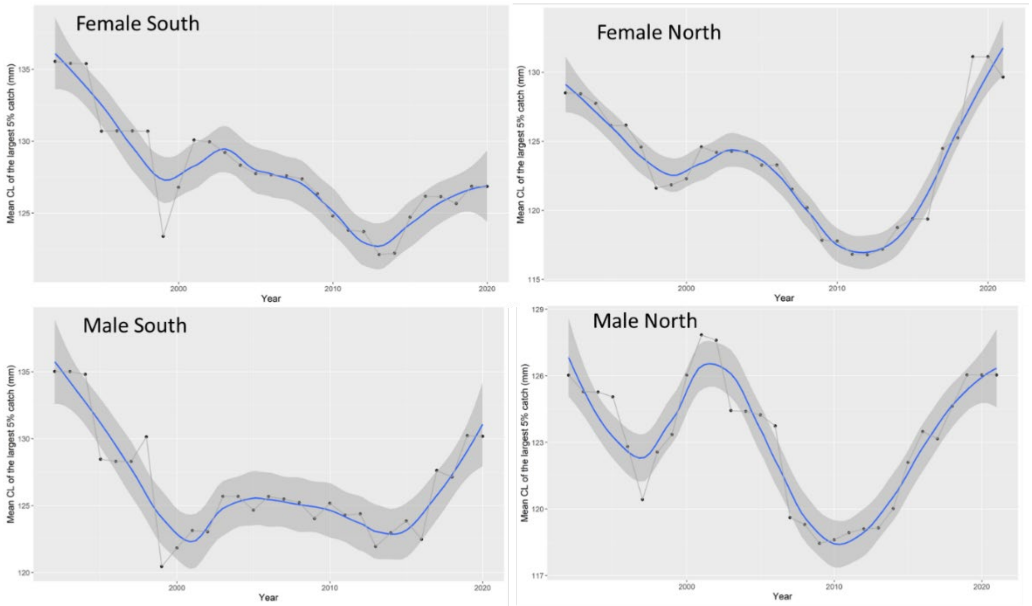


Figure 2.19. Rolling 10-year average mean carapace length of the largest 5% of the landings.

Some of these trends are at odds with the fisher knowledge that has been gathered recently. For example, many fishers feel that lobsters have decreased in size over time, and they have to go further offshore to find large lobsters. More work needs to be carried out to understand how aspects such as changes in MLS, gear creep, changes in port sampling protocols and fleet offshore shifts have affected these data.

3 ToR c) Environmental drivers and diseases

Full ToR c) Review the impact of environmental drivers (temperature, ocean acidification, climate change), diseases and pollution on important crab and lobster stocks within the ICES, Atlantic Canada and West Greenland; studying the effects on reproduction, recruitment, growth and distribution.

There have been few studies on the effect of environmental variables on crustacean fisheries and climate change impacts. In this subject, Canada seems to be ahead of the field and Canadian colleagues delivered a presentation on the correlations between climate drivers and their effects on the biomass of snow crab stocks. A new collaboration study is currently ongoing looking at the effect of environmental factors in the brown crab and snow crab fisheries. A new disease affecting brown crabs, caused by a novel protist was presented to the group in 2021 and further discussed in 2022. WGCRAB has also covered the presence of contaminants in crustaceans with an ongoing collaboration study involving several countries looking at cadmium, mercury and organic pollutants present in brown crab meat. A study on European lobsters quantified the effect of temperature and total fishing mortality to the biological process of maturity. Finally, the group debated the topic of introduced species and discussed a case study of blue crabs and their impact in local fisheries in the Mediterranean on the southeastern coast of Spain. This ToR was carried over to the next resolution (2023-2025).

3.1 Global prospects for snow crab under warming

This analysis examines relationships between exploitable biomasses of snow crab in Alaska (AK), Newfoundland & Labrador (NL), and the southern Gulf of St. Lawrence (sGSL) and a suite of lagged climate indices. Collectively, these three stocks have been among the largest on earth for most of the past three decades, but recent observations of snow crab expansions into Arctic areas suggest habitat and stock range shifts are to be expected in the coming decades. The analysis shows exploitable biomass in the AK and NL stocks have historically been in-phase with one another, with both opposing trends in the sGSL stock (Figure 3.1). These differences are shown to reflect different directional associations to the Arctic and North Atlantic Oscillations. The analysis shows variation in the strength of statistical associations between climate systems/mechanisms and latent exploitable biomasses and highlights that the interplay between atmospheric forcing and greenhouse gas warming, and how they impact sea ice and bottom temperature dynamics, will be important in regulating stock biomasses moving forward. Short-term biomass projections up to 2022 show exploitable biomass is expected to remain moderate-strong in the NL and sGSL regions and low in AK.

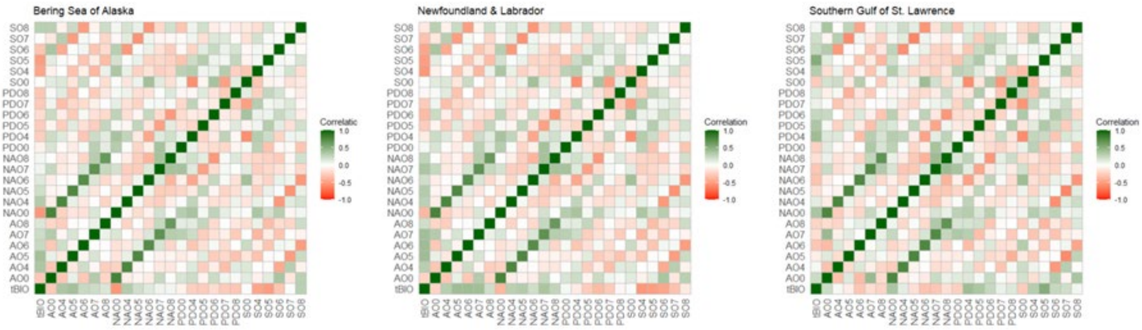


Figure 3.1. Pearson correlations between exploitable biomass indices [tBIO] and lagged atmospheric pressure systems (Southern Oscillation [SO], Pacific Decadal Oscillations [PDO], North Atlantic Oscillation [NAO], Arctic Oscillation [AO] by stock region. Numerics indicate increment of lagged relationships in years.

3.2 The role of the North Atlantic Oscillation and Long-term exploitation in the brown crab & snow crab abundance over 30 years

Increasing concern has been raised surrounding observed declines in brown crab *Cancer pagurus* landings throughout its historical exploited range in the North East Atlantic. This decline has been further strengthened by the development of three fishery independent indexes of abundance derived from trawl and dredge surveys in the North Sea, Scottish West Coast and Irish Sea highlighting declines in fishery independent abundance since 2016. Similarity between these indexes highlight the potential existence of a larger overarching driver in abundance outside of the effect of fishing mortality as each region is geographically distinct, subject to different management regimes and subsequent fishing mortality. Despite its commercial value and long exploitation history, there is currently very limited understanding around the environmental mechanisms that influences brown crab abundance or fluctuation in its recruitment. This however is not the case for all crustaceans, with the relationship between Canadian snow crab *Chionoecetes opilio* and positive phases of the North Atlantic Oscillation (NAO) resulting in greater recruitment success and lagged increases in biomass. It was hypothesised that the NAO would have a similar or inverse relationship on the abundance of *C. pagurus* in the North East Atlantic due to similar oceanographic forcing and this should be investigated. A subsequent unofficial data call was put out to all WGCRAB members asking for data contribution of long-term time series of commercial landings per unit effort data (LPUE), with a minimum of 10 years required.

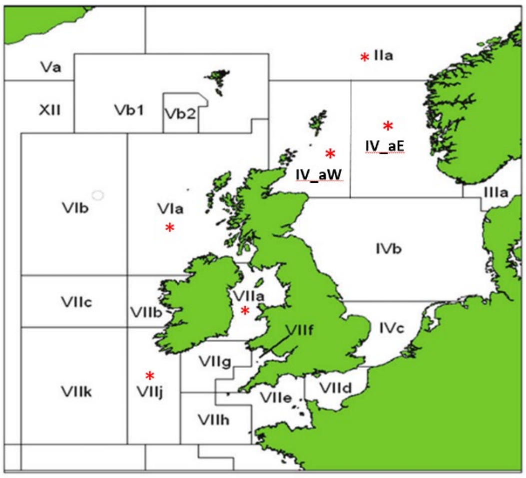


Figure 3.2. Spatial exetent of ICES areas used to assess responses of *Cancer pagurus* CPUE to the North Atlantic Oscillation

In total, data was amalgamated that encompassed 6 ICES areas (Figure 3.2) with the time series spanning 1993 to 2021, temporal coverage however varied between areas. To investigate spatial differences and similarities, six primary catch indexes were calculated: monthly effort; monthly catch; monthly CPUE; cumulative effort; cumulative catch and cumulative CPUE (Figure 3.3). Across monthly indices, similar patterns were observed across all areas (Figure 3.3). In the case of cumulative indices however, distinct differences are observed in historic areas (VII; VIIa; Via; IV_aW) compared to "new" Scandinavian fisheries (IIa; IV_aE). In the case of historical areas, cumulative effort and catch were seen to increase across the time series for all areas, whilst CPUE is seen to decline from ~2kg/pot in the 1990's in VIa to the current all-time low seen across all historic areas. When compared to "new" areas in Scandinavian ICES areas (IIa; IV_aE) all cumulative indices remain stable. Reasons behind observed differences between historic and new areas are unclear, however near stable CPUE in Scandinavian areas could be attributed to recent exploitation, effort limits and seasonal targeting behaviour of the fishery. This is different to the pattern of exploitation in the historic range, where exploitation occurs all year round and has experienced increasing levels of effort to compensate for decreasing CPUE.

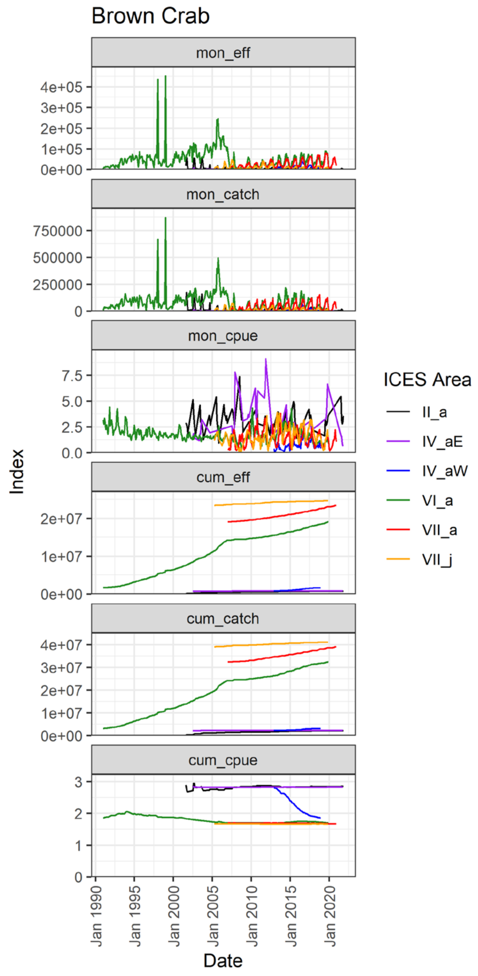


Figure 3.3. CPUE indexes calculated for each ICES area from 1993 to 2021.

Using these data, initial response of CPUE at different NAO lags was investigated. In the case of *C. pagurus*, a response at NAO lags of 7– 10 years was observed (Figure 3.4). The magnitude of response was however less than hypothesized when compared to the responses in *C. opilio*. The less pronounced response observed in *C. pagurus* could be attributed to the heavily exploited nature of *C. pagurus* stocks with variability in abundance due to fishing mortality masking broader environmental variability.

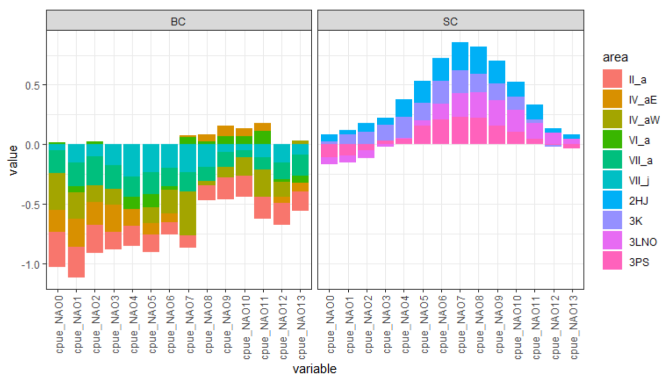


Figure 3.4. Response of Left) *Cancer pagurus* CPUE by ICES area to different NAO lags Right) *Chionoecetes opilio* by DFO assessment area to different NAO lags.

3.3 Amoebic Crab Disease (ACD)

Following reports of elevated post-capture mortality in brown crabs (*Cancer pagurus*) captured from a single site within the English Channel fishery, a novel disease (Amoebic Crab Disease (ACD)) has been described and a scientific paper published (Bateman *et al*., 2022). In recent years, there has been an industry perception of declining crab stocks, it is unclear what may be causing the reported reduced catch. Several different pathogens have been previously described infecting brown crab stocks within the UK (viruses, bacteria, fungi, and protists) (Stentiford, 2008). Many of these pathogens do not impact the fishery and pose no risk to public health. It is also documented that the prevalence of these diseases often differs between fished and non-fished (juvenile) populations, with juvenile crabs displaying a much broader range of pathogens than that observed in fished populations (Bateman *et al*., 2011).

In September 2019, the Fish Health Inspectorate (FHI) at Cefas received a report via the Southern Inshore Fisheries and Conservation Authority (IFCA) that approximately 50 dead brown crabs had been washed up on beaches on the Isle of Wight. IFCA officers subsequently visited the site but found no dead crabs in the area and it was thought that they had been taken away by the tides. The FHI are responsible for investigating any unexplained mortality event in aquatic animals in England and Wales. To investigate the reported crab mortalities, the FHI sampled crabs from the fishery. Around the time of the reported crab deaths, fishers described an increased level of crab mortality during the post-capture period with crabs appearing lethargic, and an increased number dying in the holding containers during the transit to shore.

Crab tissues were sampled using various diagnostic methods, including histology, electron microscopy, and molecular biology. Histopathology revealed a significant host response in the majority of the crab tissues, with pronounced haemocytic infiltration leading to congestion of haemal spaces, particularly within the hepatopancreas. Within these areas of host response, masses of an amoeboid parasite were identified. This was the first time this pathology and associated amoeboid cells have been identified in brown crab tissues. The intensity of infection observed varied between crabs from mild infection to severe, and it was noted that in heavy infections, significant organ and tissue damage was observed, which would presumably lead to mortality. Molecular testing indicated the presence of at least three species of amoebae: *Neoparamoeba pemaquidensis*, *N. aestuarina*, and a novel amoeba. It is not clear whether the disease is caused by the novel amoeba as a single disease agent or as part of a group of amoebic pathogens. We have named the condition identified in this study Amoebic Crab Disease (ACD) and named the newly discovered species *Janickina feisti*. To date the pathogen has only been identified in brown crabs. Preliminary study of European lobsters (*Homarus gammarus*) sampled in the same region failed to detect presence of the novel pathogen. Work is ongoing to determine the host range and geographical spread of this pathogen.

3.4 Comparison of the contaminant burden of brown crab throughout its distribution.

Brown crab (*Cancer pagurus*) is appreciated as seafood. However, the presence of contaminants can pose a threat to food safety. High values of cadmium have been detected in crabs from different origins. Within Norway, a clear trend exists with brown crab from the North containing much higher concentrations. To investigate how these findings relate to other areas, a common effort within the WGCRAB was initiated to sample crabs from different locations within the distribution of brown crab. In addition to cadmium, also the heavy metal mercury and persistent organic pollutants including dioxins, furans and PCBs were measured to evaluate differences between the different locations.

So far, between 14 and 25 crabs from each of five different locations (Northern, Western and Southern Norway, Scotland and Portugal) have already been analyzed individually for metals, while further crabs from one offshore and one inshore location from Northern France have been received, but not analyzed yet. Further sampling efforts have been initiated in Belgium and the South of Sweden. Organic pollutants were analyzed on pooled samples (n≤3 per location).

Preliminary results confirm the known trend in Norway of higher concentrations of Cd in the hepatopancreas of crabs sampled in the North. Interestingly, crabs from both Scotland and Portugal contained comparable concentrations of cadmium as the ones from Northern Norway. In addition, we found the first incidence that crabs from Western Norway had even lower concentrations than crabs from the South (Figure 3.5). Regarding mercury, the concentrations in the hepatopancreas of brown crab from Northern Norway, Southern Norway and Portugal were higher compared to Western Norway and Scotland (Figure 3.6). Possible reasons for the detected trends need to be investigated further. Factors that need to be considered are amongst others, upwelling of cadmium-rich deep sea water and growth conditions at different areas. As Hg is known to accumulate over time it might be used as indicator for growth.

The measurements of the persistent organic pollutants PCDD/F + dl-PCB indicated a trend of higher concentrations in Norway than in Scotland and Portugal, with the highest levels measured in brown crab from Southern Norway. This might be explained by a generally high pollution burden in the area. Also, for PCB6, Southern Norway had the highest concentrations. However, due to large variation and a low sample size, the results must be interpreted carefully.

The study presents novel findings and reliable results for comparison of contamination in brown crab from many parts of its distribution, serving as foundation for reliable food safety assessments.

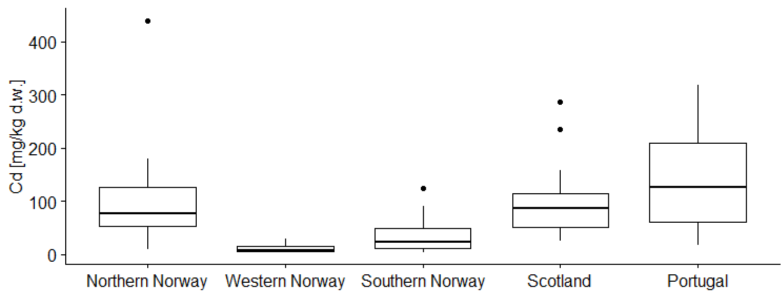


Figure 3.5. Cadmium concentration on dry weight basis in the hepatopancreas of brown crab sampled at different locations.

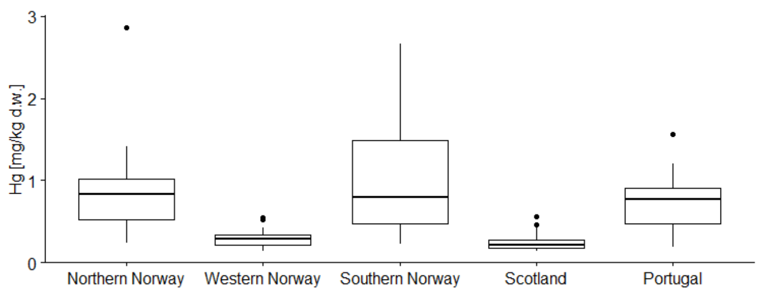


Figure 3.6. Mercury concentration on dry weight basis in the hepatopancreas of brown crab sampled at different locations.

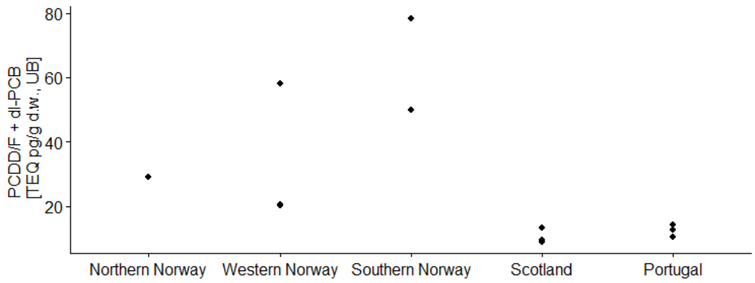


Figure 3.7. The upper bound sum concentrations of dioxins and furans (PCCDD/F) and dioxin-like PCBs (dl-PCBs) on dry weight basis in the hepatopancreas of brown crab sampled at different locations.

3.5 Temperature and fishing pressures drive geographical differences in male morphometric maturity of the European lobster (*Homarus gammarus*) across the North-East Atlantic

Work was presented at the WGCRAB 2021 meeting on research that collated existing data on morphological maturity of male European Lobster *Homarus gammarus* across the North East Atlantic, together with new data from Orkney, Wales, Jersey and Norway. Segmented regressions and principle component analysis (PCA) were used to estimate male morphological maturity for 11 populations using 7,292 lobsters. Size at morphometric maturity ranged from 73 to 110mm carapace length, with estimates derived from PCA analysis providing estimates with far smaller error compared to that of segmented regressions. General additive models were used to investigate the effect of sea surface temperatures and total mortality on morphometric maturity. Temperature had a significant non-linear relationship with sea surface temperatures with Cold (<9^{o}c) temperature resulting to lower probability of being mature, equating to larger size at maturity. Warm sea surface temperatures (>12^{o}C) resulted in increased probability of being mature, equating to smaller size at maturity. The effect of totally mortality exhibited a significant nonlinear relationship, with smaller estimates of Z equating to lower probability of being mature (greater size at maturity) with larger estimates of Z resulting in higher probability of being mature (smaller size at maturity). This is the first study to quantify the effect of temperature and total fishing mortality to the biological process of maturity in *H. gammarus*.

3.6 Blue crab (*Callinectes sapidus*) in the Spanish Mediterranean. The Mar Menor case study

The Atlantic blue crab (Rathbun, 1896) is suspected to be in the Mediterranean since 1935 (Nehring, 2011), although it was not recorded in Spanish waters until 2004, first in the Cantabrian Sea (Cabal *et al.*, 2006) and shortly afterwards in the Mediterranean coast; 2005 in the coastal lagoon Mar Menor, in the south east (Casalduero *et al.*, 2016), 2012 in the Ebro Delta, about 400 km north of Mar Menor (Castejón and Guerao, 2013), and 2014 in the mouth of the Segura River, 50 km north of Mar Menor (Gonzalez-Wanguemert and Pujol, 2016).

The invasion in the Ebro Delta was especially dramatic. In 2016, the registered catch was 0.25 tonnes and it peaked in 2020 at 309 tonnes, decreasing to nearly 250 tonnes in 2021. Over 80% of those catches are from two landing sites. Damage to local fisheries and mariculture business has been significant, with the latter having been wiped out. There is a commercial fishery for blue crab geared towards minimising the blue crab population, licensing all vessels that apply to take part in it. There is a much smaller fishery in the Albufera, a coastal lagoon in the Golfo de Valencia 200 km south of the Ebro Delta. Here, catches peaked in 2019 at 6.5 tonnes and have decreased significantly since, with <1 tonne caught in 2021. Finally, in the Mar Menor lagoon (Figure 3.8) a few kg catch was registered in 2015 but it increased exponentially to peak in 2021 at nearly 15 tonnes. This accidental catch occurs in artisanal fishing gears and for the time being there is no directed fishery. The blue crab invasion in these three localities is of special concern because they all are under different national and EU protection figures: they are all Natural Parks but also Sites of Community Importance (SCI), Special Bird Protection Areas (SBPA), and they are included in the RAMSAR wetlands list.

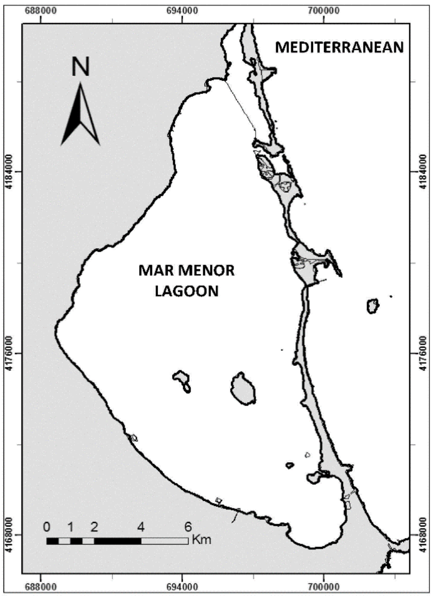


Figure 3.8. Map of the Mar Menor lagoon in the Mediterranean Sea, southeastern Spain.

The Mar Menor case

The local Fishermen's Guild manages two fish markets, one for vessels operating with SDN, OTB and LLS gears in the Mediterranean and a second one for artisanal fisheries within the lagoon. The latter supplied in 2018 40% of the total catch weight but 60% of sales. In 2021 these figures had decreased to 21% of the catch and 32% (460 000 €) of annual sales. Blue crab represented 5% of the total catch in the lagoon and although its price ranges between 3-9 €/kg it is an unwelcome catch because the increase in handling time, and the damage inflicted on the rest of the catch and the gear are not worth the market price.

Fisheries dependent sampling carried out in 2019 revealed a distinct distribution pattern among sexes and size classes, with juveniles more abundant in the eastern side of the lagoon (closer to the Mediterranean) most of the year, and females being more abundant in the 1st and 3rd quarters whereas males were more abundant in the western side and during the 2nd quarter. Stomach content analysis showed that adults prey mostly on *Penaeus kerathurus*, the main Mar Menor target species in terms of economic value (Vivas *et al*., unpublished data).

The blue crab invasion and exponential increase in abundance have occurred simultaneously to a number of eutrophication and extreme weather events: the first massive eutrophication processes occurred in September 2016 and late in 2017. In September 2019 there were torrential downpours in the region, which raised sea level in the lagoon by 0.6m in 13 hours (Castejón *et al*., 2022), followed by a high mortality event in October the same year caused by oxygen deficit

(Ruiz *et al*., 2021) and further massive eutrophication processes in the summers of 2021 and 2022, the first year with a drop in blue crab catch of nearly 50%.

More data are being collected within the ongoing project Ecology and impact of the Atlantic blue crab in Spanish Mediterranean coastal lagoons, estuaries, and adjacent waters (ECESIS), a joint effort from researchers from four organisations based on the localities more affected by the invasion. This project is looking into trophic ecology, the experimental assessment of ecosystem impacts and trophic incorporation of marine toxins in *C. sapidus*, the simulation of environmental and socioeconomic effects, abundance, habitat use and seasonality of *C. sapidus* life stages, reproductive phenology and adult migration. The project will look also into blue crab as bycatch and will outline a management /contingency plan for population control.

4 ToR d) Research and new knowledge on crab and lobster population biology

Full ToR d) Review research and generate new knowledge on vital crab and lobster population biology parameters and food safety.

This ToR is one of the main foci of the WG that generates a great deal of interest promoting useful discussions and knowledge transfer between group members. The WG discussed new projects on estimating attraction areas in trap fisheries; the use of remote electronic systems (REM) to automate catch recording on crustacean vessels and the use of cameras to assess gear efficiency of pots; development of crustacean indices of abundance for crustaceans; geographical changes in size-at-maturity of brown crab/European lobster; value of coastal marine habitats for crustaceans and use of MPAs; snow crab prey resource and consumption, genetics and possibilities of origin plus larval dispersal of snow crab in the Barents Sea. The group wishes to continue this ToR in the future and extend its focus into exploring genetics and stock structure of crab and lobster populations in the NE Atlantic. For the next draft resolution, it was proposed that a separate ToR should be created to deal with the quality of biological parameters used in stock assessments.

4.1 Estimating attraction area of pots in the brown crab fishery

Standardised landing per unit effort (LPUE) data is commonly used to provide a metric of fishery health and overall stock abundance. There are however numerous biotic and abiotic factors that can affect catchability in crustaceans and hence the relationship between LPUE and stock abundance. These include temperature/season, moulting, reproduction and the effect of conspecifics. An additional factor to consider in the interpretation of LPUE as a function of population density is understanding the area over which pots attract the target species, we termed this trapping area. Numerous methods have been trialled to estimate trapping area, this includes inferring behavioural responses from acoustically tagged individuals or recapture rates of tagged individuals released at specific distances from pots. A third method utilises changes in abundance in pots with increasing distances between pots. With the principle being that pots inherently compete with one another due to overlapping bait plume attraction areas, with increasing distance between pots reducing this overlap until pots no longer compete with one another (Figure 4.1), allowing for trapping area estimates when catch rates asymptote.

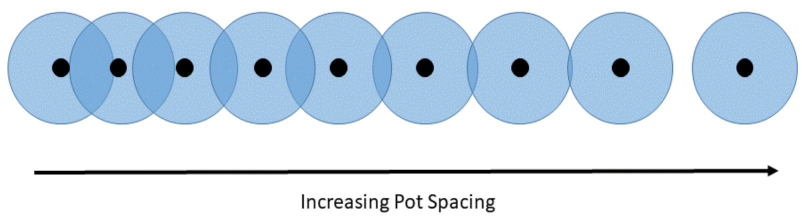


Figure 4.1. Theoretical method for estimating attraction area through increased spacing due to overlapping bait plume in baited pots.

This method was trialled in Isle of Man commercial brown crab fishery with 8 different experimental pot spacing's treatments (each consisting of 5 pots) and were fished over three 24hr periods. When hauled the number of individuals per species was recorded per pot. Trapping area was then estimated using a non-linear least square regression, incorporating both the volume of pot trapping area, string positions and degrees of trapping area overlap. In order to estimate the trapping area, a number of assumptions were made on both the shape of trapping area and the capture probability; trapping area was assumed to be circular; with capture probability <1 and capture probability declines linearly from the trap. CPUE asymptote was estimated to be at 134m, equating to a trapping area 14,187m^2, providing a density of catchable crabs of 0.00073m^2 (Figure 4.2). Catch rates were also found to be significantly different between pot spacing, with catch rates at current commercial distances 47% lower than those at the optimal distance identified during the study period.

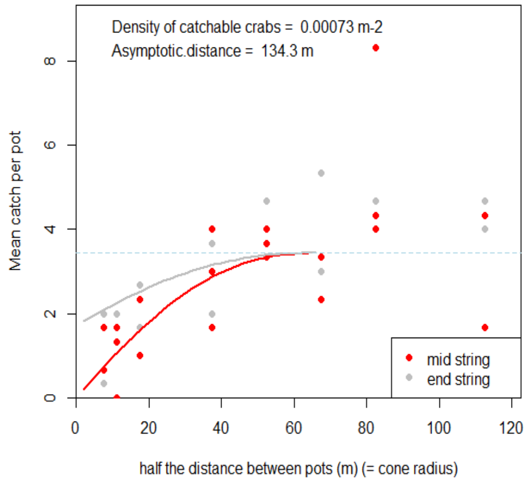


Figure 4.2. The relationship between catch per pot of Cancer pagurus and the distance between pots, and the fitted relationship for mid-string (adjacent pots in both direction, red points and line) and the end string (adjacent pot in one direction only, grey points and line).

4.2 Size at maturity of brown crab in Wales

Size at maturity was estimated for *C. pagurus* in the Irish and Celtic Seas (north and south Wales, UK, respectively, around 200 km apart) caught during 2020–2021. This was compared to the Wales-wide MLS of 140 mm carapace width (CW) and results of a similar study six years earlier (Haig *et al.*, 2016). A total of 605 crabs (311 north, 294 south) spanning a wide size range (female 19-187 mm CW, male 20-177 m CW) were sampled. Using a standard scenario where only stage 1 gonads are considered immature, CW50 (50 % of individuals are mature) for all Wales (north and south pooled) was 88 and 107 mm (males and females respectively), in line with regional literature (Figure 4.3). Significant spatial variation was found, with significantly smaller gonadal CW50 in north Wales compared to south Wales, for both males (83 cf. 94 mm) and females (98 cf. 114 mm). By 119 mm CW, a high proportion (99 % males, 50–95 % females) were gonadally mature (standard scenario), morphologically mature (most sex and area combinations), and the smallest functionally (ovigerous) and behaviourally mature females had been recorded. Evidence for a significant decline in size at maturity since the previous study was only found using a more conservative gonadal scenario, where stages 1 and 2 are considered immature. This found declines for both sexes in north Wales (and all Wales pooled) and females in south Wales. Results suggest the MLS adequately protects immature individuals, but further management measures may be needed to address reported declines (Moore *et al.*, 2022).

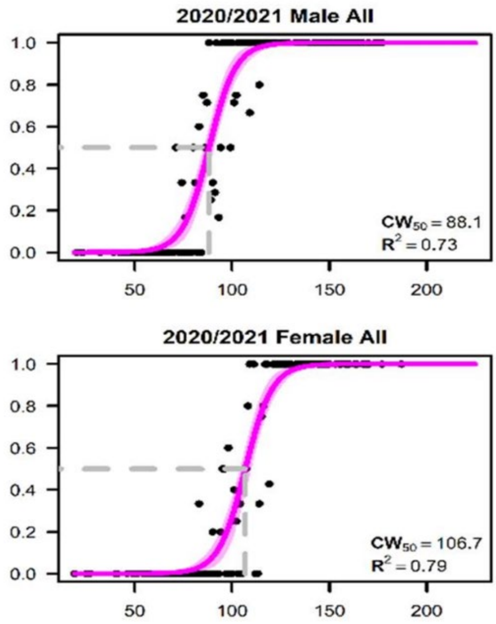


Figure 4.3. Maturity ogives for size at 50% gonadal maturity (CW50) from logistic regression for brown crab *Cancer pagurus* in Welsh waters (north and south pooled), for 2020–2021 using scenario 1 (stage 1 immature, other stages mature). Curved dashed lines represent 95% confidence intervals; the point where the straight dashed lines meet is the size at which 50 % of individuals are mature. Y axis = proportion mature.

4.3 Size at maturity of European lobster in Wales

Female lobster maturity in Wales was assessed using three approaches: Ovary maturity (physiological), observations of egg carrying (functional) and rate of change of the abdomen width to carapace length (CL) (morphological). Two scenarios of physiological maturity were tested. The first scenario classified maturity as lobsters with at least stage 4 ovaries (Dark green, but still thin and strap like filling < 50% of the dorsal cavity), with oocytes > 1mm and Ovary factor >100). A second, more precautionary scenario was also tested following observation of some lobster appearing to re-absorb developing oocytes indicating that not all animals that enter secondary vitellogenesis will continue through to spawning. This scenario required ovaries to be stage 5 in order for a lobster to be classified as mature (Plump dark green ovaries filling > 50% dorsal cavity, ovary factor > 200 and oocytes >1.2 mm). Functional maturity was assessed using at sea observer data from the months of October, November and January. Winter months are more likely to capture the peak in spawning than other times of the year. Data was available for 2014, 2015, 2019, 2020, 2021 and 2022. These data were analysed together to account for interannual variability due to environmental responses and also autumn and winter observations were limited in sample size within any one year due to weather affecting the ability to get out on fishing boats. Due to the knowledge that not all females will reproduce every year and therefore a logistic asymptote of a proportion berried of 1 was not likely to be observed, a three-parameter logistical regression was used to fix the lower asymptote to zero but allow the upper asymptote to vary below a proportion of 1. Morphological maturity was assessed using the rate of change in the abdomen width to carapace length ratio with carapace length. Segmented regression was used to model this relationship and AIC used to compare linear regression with segmented regression with one, two and three inflection points. Three inflection points best fitted the data.

The results showed that the onset of maturity was likely to be around 73 mm. This is based on the first inflection point in the morphological analysis (95%CI 71.4 mm – 75.6 mm). This is supported by the observation that of 75 mm being the smallest egg-bearing female observed across 6 years of data. The L_{50} for physiological maturity varied with the two scenarios used. Under scenario 1, there was a significant difference in the maturity ogives from north and south Wales and the L50 estimates were 83 mm and 87 mm CL respectively. The L_{90} estimate was 92 mm for both regions. Using scenario 2, the more precautionary approach, there was no significant difference between north and south Wales and the L_{50} was estimated to be 88 mm and the L_{90} to be 92 mm. Functional maturity analysis showed an upper asymptote at ~ 0.7 suggesting that over the years for which data is available, there is an average of 70% of females spawning each year. The L_{50} was 90 mm and the L_{90} was 102 mm CL. This method assumes a uniform proportion of annual or biennial spawning across the size ranges to extract the L_{50} accurately as it uses 50% of the height of the asymptote. This may not be true as annual or biennial spawning may change with size and therefore this approach may underestimate the L_{50}.

4.4 Spatial variation in the Size at Maturity of European lobster

A new study collated existing data on physiological maturity of female European Lobster *Homarus gammarus* across the North East Atlantic, together with new data from Orkney, Wales, and the Isle of Man. Using a standardized methodology, physiological estimates of size at maturity were undertaken using 1,309 lobsters from eleven locations. Carapace length (CL) at which 50% of the sampled population had reached physiological maturity (CL50) varied between populations, ranging from 82 to 92.5 mm. CL50 estimates reported here are broadly similar for historic population samples in England, but estimates for Irish samples were lower than previous results (Coleman *et al.*, 2023). Generalized Additive Models (GAM's) were used to characterize geographic patterns in size at maturity. Optimum monthly sea surface temperature (OPTIMNTH) had a significant and non-linear effect on the probability of being sexually mature at a given size in different populations. This is consistent with a thermal optimum previously demonstrated in absolute growth.

4.5 The lobster camera project (Cefas)

The aim of the project is to improve the quality and quantity of data available for stock assessments of data-poor crab and lobster fisheries in three UK fisheries using fisheries-dependent monitoring with dedicated in-creel imaging systems. The aim addresses the need for an effective abundance index by recording crustacean presence within and in the vicinity of creels to aid stock assessments and de-couple the link between catch statistics and abundance estimates. Three fisheries are targeted for data collection: the Holderness inshore and offshore lobster fleets, the Orkney inshore creel fishery and the Isle of Man's Territorial seas lobster and crab fisheries. The project brings together three distinct scientific organisations (Cefas, Heriot Watt University and Bangor University) and expert from the industry bodies (Holderness Fishing Industry Group, Orkney Sustainable Fisheries).

Cefas LobsterCam captures images at regular intervals from twin cameras over the course of the first 24-30 hours of creel soak time. The cameras are orientated to observe the seabed adjacent to the creel (plus the creel entrance when possible) and the parlour/entrance tunnel within the creel (Figure 4.4). The Heriot-Watt system consists of GoPro cameras and diving lights attached to a baited creel, recording approaches to the bait and the adjacent seabed. In the early stages of the project, at sea trials permitted the identification of some issues with the system start up and download processes. In collaboration with the Holderness fishery, technical fixes and updates were conducted. Although, the COVID-19 pandemic has had a significant impact, at sea trials were conducted and underwater images were successfully captured. The project is still in the data-collection phase, there have been further successful deployments of both the dual camera system in The Holderness region and the meshless system in the Isle of Man. There has been over 450 hours of equipment deployed to date for the project with further deployments planned for Q4. Regular updates are given to the industry forums aiding in developing Fisheries Management Plans for crab and lobster. The interest from stakeholders in the project remains high and has increased by the deployment of systems by fishermen in the Holderness fishery.

Figure 4.4. Images from the LobsterCam with one of the cameras pointing inside the pot (left) and the other pointing towards the seabed (right).

4.6 Infaunal and epifaunal secondary production in the Barents Sea, with focus on snow crab prey resources and consumption.

Since the first observation of snow crab (*Chionoecetes opilio*) in the Barents Sea the population has increased significantly and supports now a commercial fishery on the Norwegian shelf. To investigate whether the availability of benthic prey organisms may support a continued geographical snow crab expansion in the Barents Sea, benthic invertebrate production was studied across the central parts of the Barents Sea and around Svalbard. Benthic invertebrate secondary production (P) was estimated from annual production to biomass ratios (P/B ratio). Over several years, data was collected from 66 stations using grab and beam trawl. The annual productivity (P/B) was estimated using a multiparameter artificial neural network model. Mean infaunal productivity and production were found to be 0.43 yr(-1) and 38.4 g ww m(-2) yr(-1), respectively, while the epifaunal production was considerably lower with 2.5 g ww m(-2) yr(-1).The proportions of epi- and infaunal production suitable as prey for snow crab were therefore found to be 98 and 96%, respectively. Another important finding was that areas close to the Polar Front represent the most attractive snow crab foraging region, having the highest benthic secondary production, high estimated primary production, and bottom water temperatures within the snow crab's preferences. Food availability is, therefore, not expected to be a hindrance to further population expansion of the snow crab in the Barents Sea (Holte *et al.*, 2022).

4.7 Modelled dispersal of snow crab larvae and potential settlement areas in the western Barents Sea.

Since the mid-1990s a snow crab (*Chionoecetes opilio*) population has been established in the eastern Barents Sea. Spawning females and newly hatched larvae are now also found in the central Barents Sea, warranting speculations on a further westward colonization by pelagic larvae. In a new study, we model the potential for larval dispersal and settlement into uncolonized areas in the western Barents Sea. We used a biophysical model of ocean currents and hydrography, coupled with a Lagrangian dispersal algorithm and larval survival functions as response to temperature. The model results predict limited dispersal from the central Barents Sea to western areas, primarily due to a mismatch between prevailing temperature regimes and temperature tolerances for the different snow crab larval stages. In addition, it was found limited westward transport of water masses with temperatures that would allow completion of the pelagic snow crab larval development. It is speculated therefore that for larvae to successfully supply benthic recruits to the remaining uncolonized areas in the western Barents Sea, adult crabs would first need to establish new spawning aggregations, for example along the western slopes of the Barents Sea shelf. Immediate implications are limited potential for expanding the fishery to the western areas of the Barents Sea. However, the adult distribution may change in the future and influence settlement pattern (Huserbråten *et al*., 2023).

References

Bateman, K., Stentiford, G., Kerr, R., Hooper, C., White, P., Edwards, M., Ross, S., *et al*. 2022. Amoebic crab disease (ACD) in edible crab *Cancer pagurus* from the English Channel, UK. Diseases of Aquatic Organisms, 150: 1-16.

Bateman, K. S., Hicks, R. J., and Stentiford, G. D. 2011. Disease profiles differ between non-fished and fished populations of edible crab (*Cancer pagurus*) from a major commercial fishery. ICES Journal of Marine Science, 68: 2044-2052.

Blampied, S. 2022. A socio-economic and ecological approach to informing sustainable fisheries management in Jersey, Channel Islands. PhD. Plymouth University.

Cabal, J., Pis-Millán, J., and Arronte-Prieto, J. C. 2006. A new record of *Callinectes sapidus* Rathbun, 1896 (Crustacea: Decapoda: Brachyura) from the Cantabrian Sea, Bay of Biscay, Spain. Proceedings of the National Academy of Sciences of the United States of America, 1: 186-187.

Casalduero, F. G., Esplá, A. R., Muñoz, A. I., Castillo, F. G., Hernández, F. M., and González-Carrión, F. 2016. Alloctonous Marine Invertebrates in the Mar Menor Lagoon. *In* Mar Menor: una laguna singular y sensible. Evaluación científica de su estado, pp. 157-178. Instituto Español de Oceanografía, Ministerio de Economía y Competitividad.

Castejón, D., and Guerao, G. 2013. A new record of the American blue crab, *Callinectes sapidus* Rathbun, 1896 (Decapoda: Brachyura: Portunidae), from the Mediterranean coast of the Iberian Peninsula. BioInvasions Records, 2: 141-143.

Castejón, F. L., Cervera, J. G., Oliver, N. A., Meroño, D. T., and de Mesas, C. R. 2022. Modelling of a strong flood event on the Mar Menor coastal lagoon with ROMS.

Coleman, M. T., Garratt, M., Hold, N., Bloor, I. S., Jenkins, S. R., Porter, J. S., Tully, O., *et al*. 2023. A standardized assessment of geographic variation in size at maturity of European lobster (*Homarus gammarus* L.) in the North East Atlantic. ICES Journal of Marine Science, 80: 911-922.

Cousido-Rocha, M., Cerviño, S., Alonso-Fernández, A., Gil, J., Herraiz, I. G., Rincón, M. M., and Ramos, F. 2022. Applying length-based assessment methods to fishery resources in the Bay of Biscay and Iberian Coast ecoregion: Stock status and parameter sensitivity. Fisheries Research, 248: 106197.

Froese, R., and Sampang, A. 2012. Proxies for estimation of relative fishing mortality when biomass is unknown. ICES.

Froese, R., and Sampang, A. 2013. Potential indicators and reference points for good environmental status of commercially exploited marine fishes and invertebrates in the German EEZ.

Gonzalez-Wanguemert, M., and Pujol, J. A. 2016. First record of the atlantic blue crab *Callinectes sapidus* (Crustacea: Brachyura: Portunidae) in the Segura river mouth (Spain, southwestern Mediterranean Sea). Turkish Journal of Zoology, 40: 615-619.

Haig, J. A., Bakke, S., Bell, M. C., Bloor, I. S. M., Cohen, M., Coleman, M., Dignan, S., *et al*. 2016. Reproductive traits and factors affecting the size at maturity of *Cancer pagurus* across Northern Europe. ICES Journal of Marine Science, 73: 2572-2585.

HaV 2015. Krabba – Minimimått, fredningstid och fångstbegränsningar.

HaV 2018. Regler för fiske, landning och försäljning av krabba och krabbklor. Artdatabanken. 2022. Krabbtaska, *Cancer pagurus*.

Holte, B., Fuhrmann, M. M., Tandberg, A. H. S., Hvingel, C., and Hjelset, A. M. 2022. Infaunal and epifaunal secondary production in the Barents Sea, with focus on snow crab (*Chionoecetes opilio*) prey resources and consumption. ICES Journal of Marine Science, 79: 2524-2539.

Hordyk, A., Ono, K., Sainsbury, K., Loneragan, N., and Prince, J. 2014. Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. ICES Journal of Marine Science, 72: 204-216.

Hordyk, A. R., Ono, K., Prince, J. D., and Walters, C. J. 2016. A simple length-structured model based on life history ratios and incorporating size-dependent selectivity: application to spawning potential ratios for data-poor stocks. Canadian Journal of Fisheries and Aquatic Sciences, 73: 1787-1799.

Huserbråten, M., Hjelset, A., Danielsen, H., Hvingel, C., and Agnalt, A. 2023. Modelled dispersal of snow crab (*Chionoecetes opilio*) larvae and potential settlement areas in the western Barents Sea. ICES Journal of Marine Science: fsad062.

ICES 2012. Report of the Workshop on the development of quantitative assessment methodologies based on LIFE-history traits and exploitation characteristics (WKLIFE), 13-17 February 2012, Lisbon, Portugal. ICES WKLIFE REPORT: 1-134.

ICES 2018. Report of the ICES Workshop on the Development of Quantitative Assessment Methodologies based on Life-history traits, exploitation characteristics, and other relevant parameters for stocks in categories 3–6 (WKLIFE VII), 2–6 October 2017, Lisbon, Portugal. ICES. CM 2016/ACOM:59. 106 pp.

ICES 2021. Working Group on the Biology and Life History of Crabs (WGCRAB; outputs from 2019 meeting). ICES Scientific Reports. 3:32. 68 pp. https://doi.org/10.17895/ices.pub.8003.

Kleiven, A. R., Espeland, S. H., Stiansen, S., Ono, K., Zimmermann, F., and Olsen, E. M. 2022. Technological creep masks continued decline in a lobster (*Homarus gammarus*) fishery over a century. Scientific reports, 12: 3318.

Kleiven, A. R., Lyle, J., Ferter, K., Espeland, S. H., Kleiven, P. J. N., Christensen, L., and Vølstad, J. H. 2019. Hummerfisket 2017 og 2018: Innsats og fangst. 39.

Knutsen, J. A., Kleiven, A. R., Olsen, E. M., Knutsen, H., Espeland, S. H., Sørdalen, T. K., and Thorbjørnsen, S. H. 2022. Lobster reserves as a management tool in coastal waters: Two decades of experience in Norway. Marine Policy, 136: 104908.

Marcussen, J. B. 2022. Fishing for more data: Exploratory stock assessment of the data-limited brown crab (*Cancer pagurus*) stock in Norway. University of Agder.

Marcussen, J. B., Nedreaas, K., Søvik, G., and Zimmermann, F. 2022a. Taskekrabbetokt: Molde – Frøya 2021. 12-2022. Toktrapport 2022 Bergen, Norway.

Marcussen, J. B., Søvik, G., Jenssen, M., and Zimmermann, F. 2022b. Status: Taskekrabbe (*Cancer pagurus*) i Norge. Tilstand, trender og bestandsvurderingsmetoder. Rapport fra havforskningen 2022 Bergen, Norway.

Marine Resources 2019. Government of Jersey Marine Resources Annual Report 2019.

McMinn, C., and Prodöhl, P. 2021. Report on Northern Ireland lobster science. Unpublished. https://www.afbini.gov.uk/sites/afbini.gov.uk/files/publications/Lobster%20Science%202017-2020%20Report-Final%201.3.pdf.

Mesquita, C., Dobby, H., Pierce, G. J., Jones, C. S., and Fernandes, P. G. 2021. Abundance and spatial distribution of brown crab (*Cancer pagurus*) from fishery-independent dredge and trawl surveys in the North Sea. ICES Journal of Marine Science, 78: 597-610.

Mesquita, C., Ellis, A., Miethe, T., and Dobby, H. 2023. Crab and lobster fisheries in Scotland: Results of stock assessments 2016–2019. Scottish Marine and Freshwater Science, Vol 14 No 5: 123p.

Miethe, T., and Dobby, H. 2015. Selection of length-based indicators for shellfish stocks and fisheries. Working Document, ICES report WKLIFE V 2015 ICES CM 2015/ACOM: 56.

Mildenberger, T., Kokkalis, A., and Berg, C. 2021. Guidelines for the stochastic production model in continuous time (SPiCT).

Mildenberger, T. K., Berg, C. W., Kokkalis, A., Hordyk, A. R., Wetzel, C., Jacobsen, N. S., Punt, A. E., *et al*. 2022. Implementing the precautionary approach into fisheries management: Biomass reference points and uncertainty buffers. Fish and Fisheries, 23: 73-92.

Mildenberger, T. K., Berg, C. W., Pedersen, M. W., Kokkalis, A., and Nielsen, J. R. 2020. Time-variant productivity in biomass dynamic models on seasonal and long-term scales. ICES Journal of Marine Science, 77: 174-187.

Moore, A. B., Delargy, A. J., Cann, R. P., Heney, C., Le Vay, L., Lincoln, H., McCarthy, I. D., *et al*. 2022. Spatial and temporal variation of size at maturity in an intensive crustacean fishery with limited management. Fisheries Research, 255: 106450.

Nehring, S. 2011. Invasion history and success of the American blue crab *Callinectes sapidus* in European and adjacent waters. *In* In the wrong place-alien marine crustaceans: distribution, biology and impacts, pp. 607-624. Springer.

Pedersen, M., Kokkalis, A., Mildenberger, T., and Berg, C. 2021. Handbook for the Stochastic Production model in Continuous Time (SPiCT). SPiCT R package handbook.

Pedersen, M. W., and Berg, C. W. 2017. A stochastic surplus production model in continuous time. Fish and Fisheries, 18: 226-243.

Polacheck, T., Hilborn, R., and Punt, A. E. 1993. Fitting surplus production models: comparing methods and measuring uncertainty. Canadian Journal of Fisheries and Aquatic Sciences, 50: 2597-2607.

Punt, A. E. 2003. Extending production models to include process error in the population dynamics. Canadian Journal of Fisheries and Aquatic Sciences, 60: 1217-1228.

Ruiz, J. M., Clemente-Navarro, P., Mercado, J. M., Fraile-Nuez, E., Albentosa, M., Marín-Guirao, L., and Santos, J. 2021. Nuevo evento de mortalidad masiva de organismos marinos en el Mar Menor: contexto y factores. Informe de asesoramiento técnico del Instituto Español de Oceanografía (IEO). 24pp.

Stentiford, G. D. 2008. Diseases of the European edible crab (*Cancer pagurus*): a review. ICES Journal of Marine Science, 65: 1578-1592.

Vivas, M., García-Rodríguez, E., Muñoz-Vera, A., Barcala-Bellod, E., and Guijarro-García, E. unpublished data. Trophic interactions and reproductive ecology of blue crab (*Callinectes sapidus* Rathbun, 1896) in a protected coastal lagoon in SE Spain; evidence for predation impact.

Zimmermann, F., Kleiven, A. R., Ottesen, M. V., and Søvik, G. 2022. Inclusion of recreational fishing in data-limited stocks: a case study on Norway lobster (*Nephrops norvegicus*) in Norway. Canadian Journal of Fisheries and Aquatic Sciences, 79: 969-978.

Annex 1: List of participants

Name	Institute	Country (of institute)	Email
Carlos Mesquita (chair)	Marine Directorate	United Kingdom	carlos.mesquita@gov.scot
Ailsa Ellis	Marine Directorate	United Kingdom	ailsa.ellis@gov.scot
Alec Moore	Bangor University	United Kingdom	a.moore@bangor.ac.uk
Alexander Plaster	Department of Environment, States of Jersey	United Kingdom	a.plaster@gov.je
Alexandros Kokkalis	National Institute of Aquatic Resources	Denmark	alko@aqua.dtu.dk
Alf Ring Kleiven	Institute of Marine Research	Norway	alf.ring.kleiven@hi.no
Ann Merete Hjelset	Institute of Marine Research	Norway	ann.merete.hjelset@hi.no
Ann-Lisbeth Agnalt	Institute of Marine Research	Norway	ann-lisbeth.agnalt@hi.no
Carrie McMinn	Agri-food and Biosciences Institute	United Kingdom	carrie.mcminn@afbini.gov.uk
Carsten Hvingel	Institute of Marine Research	Norway	carsten.hvingel@hi.no
Charlie Heney	Bangor University	United Kingdom	c.heney@bangor.ac.uk
Chun Chen	Wageningen IMARES	Netherlands	chun.chen@wur.nl
Darrell Mullowney	Northwest Atlantic Fisheries Center	Canada	darrell.mullowney@dfo-mpo.gc.ca
Elena Guijarro	The Spanish Institute of Oceanography	Spain	elena.guijarro@ieo.csic.es
Emily Roebuck	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	emily.roebuck@cefas.gov.uk
Fabian Zimmermann	Institute of Marine Research	Norway	fabian.zimmermann@hi.no
Francis Binney	Department of Environment, States of Jersey	United Kingdom	f.binney@gov.je
Georgina Vickery	University of Bergen	Norway	Georgina.Vickery@student.uib.no
Guillermo Martin	Marine Institute	Ireland	guillermo.martin@marine.ie
Hanna Danielsen	Institute of Marine Research	Norway	hanna.danielsen@hi.no
Idongesit Ikpewe	Marine Directorate	United Kingdom	idongesit.ikpewe@gov.scot

Jack Emmerson	Bangor University	United Kingdom	j.emmerson@bangor.ac.uk
Jan Sundet	Institute of Marine Research	Norway	jan.h.sundet@hi.no
Johanna Bjånes Marcussen	University of Agder	Norway	johanna.bjaanes.marcussen@hi.no
Johanna-Luise Kozák	Swedish University of Agricultural Sciences	Sweden	johanna.luise.kozak@slu.se
Kelly Bateman	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	kelly.bateman@cefas.gov.uk
Marcel Rozemeijer	Wageningen IMARES	Netherlands	marcel.rozemeijer@wur.nl
Mark James	University of St Andrews	United Kingdom	maj8@st-andrews.ac.uk
Martial Laurans	Ifremer - Centre de Brest	France	martial.laurans@ifremer.fr
Martin Wiech	Institute of Marine Research	Norway	martin.wiech@hi.no
Matthew Coleman	Bangor University	United Kingdom	m.coleman@bangor.ac.uk
Natalie Hold	Bangor University	United Kingdom	n.hold@bangor.ac.uk
Oliver Tully	Marine Institute	Ireland	oliver.tully@marine.ie
Paul Chambers	Department of Environment, States of Jersey	United Kingdom	p.chambers@gov.je
Rosslyn McIntyre	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	rosslyn.mcintyre@cefas.gov.uk
Samantha Blampied	Department of Environment, States of Jersey	United Kingdom	s.blampied2@gov.je
Samantha Stott	Centre for Environment, Fisheries and Aquaculture Science	United Kingdom	samantha.stott@cefas.gov.uk
Sarah Clarke	Marine Institute	Ireland	sarah.clarke@marine.ie
Snorre Bakke	Norwegian University of Science and Technology	Norway	snorre.bakke@ntnu.no
Stephanie Boudreau	Fisheries and Oceans Canada - Gulf Region (Moncton, New Brunswick)	Canada	stephanie.boudreau@dfo-mpo.gc.ca

Annex 2: Resolutions

The **Working Group on the Biology and Life History of Crabs** (WGCRAB), chaired by Carlos Mesquita, Scotland, UK, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	10–12 November	online meeting		
Year 2021	9–11 November	online meeting		
Year 2022	8-10 November	ICES HQ, Copenhagen, Denamrk	Final report by 20 December 2022 to SCICOM	

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a	Compile data on landings, discards, effort and catch per unit effort (CPUE) to provide standardised CPUE, size frequency and research survey data for the important crab and lobster (*Homarus*) fisheries in the ICES area, Atlantic Canada and Greenland. Maps will be produced to synthesise the data. Part of this data will be submitted to the ICES Data Centre.	Crab and lobster fisheries are economically important for many coastal populations in Europe and Canada and more specifically where the demise of fin fish occurred.	5.4; 4.1; 3.2	3 years	Landings, discards, effort and catch data on listed species from each country. WG report.
b	The EG will collate stockassessment data for areas where the information is available. The working group will review methodologies to develop suitable standardized	The data available for each fishery vary greatly. In some, the main management rules are quotas, licences and limitation of fishing gears to control the effort. The status of many stocks remains uncertain. Thus,	5.1; 5.3	3 years	Report on evaluation of assessement methods.

	reference points for the management of the different stocks. Explore and apply common assessment methods for crab and lobster stocks using available data including length distributions and abundance indices.	developing robust evaluation methods for many fisheries is necessary.			
c	Review the impact of environmental drivers (temperature, ocean acidification, climate change), diseases and pollution on important crab and lobster stocks within the ICES, Atlantic Canada and West Greenland; studying the effects on reproduction, recruitment, growth and distribution.	Crabs and lobsters, as many other species are impacted by environmental paramaters. In the actual situation of climate change, WGCRAB must investigate the main importance on the recruitment and biomass trends.	5.2; 2.1	3 years	Highlight important issues to be basis for research on effect of climate changes on important crab stocks. WG report chapter.
d	Review research and genereate new knowledge on vital crab and lobster population biology parameters and food safety.	Biological paramaters are important for stock assessments and improved data will lead to more reliable outputs.	1.7; 1.8	3 years	Updated any new knowledge on crucial stock parameters for any crab and lobster stocks. Any updates or new knowledge will be outputted into summary tables.

Summary of the Work Plan

Year 1	Annual standard outputs for a) and b). Continue analysis for c) and d).
Year 2	Annual standard outputs for a) and b). Continue analysis for c) and d).
Year 3	Annual standard outputs for a) and b). Complete report on analysis, research and report incuding all work for ToRs c) and d).

Supporting information

Priority	High. In Canada as in Europe, fishermen activities are highly dependent of crab and lobster stocks. Morevover, available data vary depending on the country, which is why work on the assessment methods need to be continued, particularly on those countries where fishing data exist allowing the development of new approaches. The aim is to ensure statistically sound assessments of the main crab and lobter stocks in order to provide suitable conditions to develop good management practices and stability of all dependent fleets. The activity of the Group is therefore considered to be of high priority in particular if its activity can move towards resource assessment without losing biological inputs.

Resource requirements	The research programmes which provide the main input to this group are underway, and resources are already committed. The additional resources required to undertake activities in the framework of this group is not expected to be significant.
Participants	The Group is normally attended by some 10–15 members and guests.
Secretariat facilities	Standard support to WG
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	Potential linkages to some EGs under ACOM
Linkages to other committees or groups	
Linkages to other organizations	

Annex 3: Fishery and Survey Data Tables

Table A1. Stock summary for *Cancer pagurus* by country, including summaries of fishery indicators, analytical assessments and biological parameters.

	Ireland	**Scotland**	**England**	**France**	**Norway**	**Northern Ireland**	**Sweden**	**Jersey**	**Wales**
Number of stocks	4	12	6	3	1		2	1	1
Stock areas	Malin	Clyde	Central North Sea	Eastern Channel	Whole Norwegian coast, Swedish border to Tromsø	37E3, 37E4, 38E4, 39E3, 39E4	Skagerrak		
	Irish Sea	East Coast	Southern North Sea	Western Channel			Kattegat		
	SW Ireland	Hebrides	Eastern Channel	Celtic Sea					
	Celtic Sea	Mallaig	Western Channel						
		North Coast	Celtic Sea						
		Orkney	Irish Sea						
		Papa							
		Shetland							
		South East		1985-2022					
		South Minch		1985-2022 (Offshore), 2000-2022 (Inshore)					
		Sule		1985-2022 (Offshore), 2000-2022 (Inshore)					
		Ullapool		2015-2022					
Indicator				2000-2022, not every year					
Landings	1990-2022	1974-2017	1983-2022		1914-2022	2006-2021	1950-2022	2007-2022	2010 - 2022
Effort			1983-2022			2006-2021	No	2007-2022	2010 - 2022 Only Engine power and dates, no pot numbers
LPUE	Yes: 1991-2006: Offshore From 2000's: Self-sampling		1983-2022	No	2001-2022	2006-2021	Yes	2007-2022	Not yet calculated
DPUE	Yes: Early 2000's-onwards From 2000's: Self-sampling		No	Yes (SPiCT), in progress	2001-2022	2010-2022		2004-2022	No
Size frequency data	2008-onwards	1974-2017	1983-2013 (for most assessment units)	No	2001-2022	2010-2022	No	2004-2022	1983 - 2022, collection method not standardised
Others				No					
Analytical assessment methods									
LCA	No	Yes	Yes (length-based VPA excluding Irish Sea		No	No	No	No	CEFAS occasionally have done this
Production	Yes (SPiCT)	No			One test		No	No	No
Change in ratio	No	Yes		Yes			No	Yes	No
Depletion methods	No	No		In progress			No	No	No

Others	No		LPUE selected logbook vessels	No	Index LPUE from selected logbook vessels	Length-based indicator			
Data sources				No					
Surveys			1989 (EC & WA), 1993 (NS) + Various non targeted		No				
Larval	No	No		Yes		No	No	No	No
Juvenile index /biomass	No	No		Yes		No	No	Yes	No
Adult index/biomass	No	No		Yes	No	No	No	Yes	No
Non target surveys	No	Scallop dredge		No	No	bycatch recorded in all AFBI surveys	No	Yes	No
Commercial				Yes>12m					
Observer/self reporting/reference fleet	Yes(Observer, self-reporting and reference fleet)	Observer	Selected logbook vessels from 1985	Yes	Reference fleet	Observer	No	Reference fleet	No
Size frequency data	Yes (Observer at sea and Port sampling)	Yes	Yes		Yes	Yes 2010-2022	No	Yes	Some, but data quality issues
Logbooks	Yes (EU logbooks >10m; Sales notes <10m)	Yes (EU logbooks)	Yes		No	Yes Monthly Shellfish Returns (weekly in Strangford Lough)	Yes (EU logbooks)	Yes	Yes
Tag returns	Not currently	Yes	Yes	?	No	Yes	No	Yes	No
VMS	Yes (>12m)	Yes (boats > 12m)	Yes (Commercial in-confidence)	No	Yes (boats >15m)	Yes boats > 12m; boats in Strangford Lough	No	Yes (>12m)	yes, all vessels
Electronic logbooks	Yes over 15m	No	No	No	Yes (phased in for boats <15m from 2022)	No	No	No	Yes
Others				No					
Biological parameters				No					
M	No	0.1	0.1 and 0.2 assumed feasible scenarios		No	0.1	No		No
Growth data	No	K_m=0.197 ; $Linf_m$=220; K_f=0.172 ; $Linf_f$=220;	k=0.191 (female), 0.196 (male). Linf 240mm CW	in progress		Km=0.099 ; Linfm=258; Kf=0.07 ; Linff=259;	No		No
Fecundity	No		a=0.0187 and b=0.0268, $f=ae^{bl}$	No			with 6-8 years (Ungfors A. 2008)		No
Size at maturity	Haig *et al.*, 2016	140 - 150	Regional 89-105 (male), 110-126 (female)	No		F=127, M=125	females 130 mm, males 110 mm (Ungfors A. 2008)		Haig *et al* 2015, Moore *et al* 2022
Others	Size-Weight relationship	Terminal F=0.5		in progress		LoptM=196.3,90LinfM=232,LF=MM=165, LcM=134; LoptF=172.4,90LinfF=233,LF=MF=177, LcF= 149.5			
Analytical assessment outputs									
Biomass	Yes	Yes	Yes		No		No		No
Spawning stock	No	No	Yes		No		No		No
Recruitment	No	No	No		No		No		No
Fishing mortality	Yes	Yes	Yes		No		No		No

Table A2. Stock summary for *Chionoecetes opilio* by country, including summaries of fishery indicators, analytical assessments and biological parameters.

	Canada	Canada Southern Gulf	Greenland^	Norway^	Russia^	France
Number of stocks		4	6	1	1	1
Stock areas	NAFO 2H, 2J, 3K, 3L, 3N, 3O, 3Ps, 4R	Eastern Canada, Southern Gulf of St., Lawrence	West coast	Barents Sea	Barents Sea	3PS
Indicator						
Landings	1979-2022	1979-2022	1996 - 2015	2013-	2013 - 2014	1996 - 2022
Effort	1979-2022	1979-2022	2003 - 2015	No	2013 - 2014	1996 - 2022
LPUE/CPUE	1979-2022	1985-2022	2000 - 2015	No	2013 - 2014	1996 - 2022
DPUE	1999-2022	Not estimated but possible to do				
Size frequency data	1979-2022	1989-2022	1997 - 2016	2004-	2004 - 2014	Yes, few data
Others	1979-2022	1989-2022	1997 - 2016		2004 - 2014	
Analytical assessment methods						
LCA	No	No	No			No
Production	Yes	No	No		Yes	No
Change in ratio	No	No	Yes			Yes
Depletion methods	Yes	Yes 1985-1989	No			No
Others	Stratified Random Biomass Estimation	Yes 1989-2014 (Trawl survey)	Yes		Yes 2004-2014 (Trawl survey	Yes
Data sources						
Surveys		Yes 1989-2014 (Trawl survey)	Yes 1997 - 2016		Yes 2004-2014	No
Larval	No	Sporadically	No	No	No	No
Juvenile index /biomass	Yes	Yes (abundance estimates)	Index	No	Yes	Index
Adult index/biomass	Yes	Yes (abundance & Biomass estimates)	index	No	Yes	Index
Non target surveys	Yes	September groundfish trawl survey		No	Yes	
Commercial						
Observer/self reporting/reference fleet	Yes	At sea observer at the coverage of approximately 20% of total sea days	Fleet	No	Yes	Yes
Size frequency data	Yes	Yes	No	No	Yes	Yes, few data
Logbooks	Yes	Yes	Yes	No	No	Yes
Tag returns	Yes	Between 1985 and 2000	Yes	No	No	No
VMS	Yes	Yes	No	No	Yes	No
Electronic logbooks	No	No	No	No	Yes	No
Others	Dockside Monitored Landings					
Biological parameters						
M	Yes	0.47 (2013)	0.2	No	No	No
Growth data	Yes	Yes	Yes	No	Yes	No
Fecundity	Yes	Yes (until 2010)	Yes	No	Yes	No
Size at maturity	Yes		52 - 150 mm CW	No	Yes	No
Others	Environment (Temperature)					
Analytical assessment outputs						
Biomass	Yes	Yes	Yes		No	No
Spawning stock	No	Yes			No	No
Recruitment	Yes	Yes	Yes		No	No
Fishing mortality	Yes	Yes			No	No

^ No updates provided since the previous WGCRAB report (ICES, 2021)

Table A3. Stock summary for *Paralithodes camtschaticus* by country, including summaries of fishery indicators, analytical assessments and biological parameters.

	Norway	Russia^
Number of stocks		
Stock areas (cross reference to map)	ICES Area 03	ICES Area Ib Russian coast of South-East of Barents Sea
Indicator		
Landings	1994-2022	1994-2018
Effort	1994-2022	1994-2018
LPUE		1994-2018
DPUE		
Size frequency data	Yes	Yes
Others		
Analytical assessment methods		
LCA		
Production	2011-2022	
Change in ratio		
Depletion methods		2010-2014
Others		CSA (2006-2013)
Data sources		
Surveys		
Larval		
Juvenile index /biomass		Yes
Adult index/biomass	Annual	Yes
Non target surveys		Yes
Commercial		
Observer/self reporting/reference fleet		Yes
Size frequency data		Yes
Logbooks	Yes	No
Tag returns		Yes
VMS	Yes	Yes
Electronic logbooks	No	Yes
Others		
Biological parameters		
M	0.2	0.08961
Growth data	Increment and moulting frequency	Yes
Fecundity	Yes	Yes
Size at maturity	Yes	Yes
Others		
Analytical assessment outputs		
Biomass	Yes	Yes
Spawning stock	Yes	No
Recruitment	Yes	Yes
Fishing mortality	Yes	Yes

^ No updates provided since the previous WGCRAB report (ICES, 2021)

Table A4. Stock summary for *Maja brachydactyla* by country, including summaries of fishery indicators, analytical assessments and biological parameters.

	England	Scotland	France	Ireland	Jersey Channel Islands
Number of stocks				2	1
Stock areas (cross reference to map)				SW Ireland	Western Channel
Indicator					
Landings	1983-2022	2006-2022	1973-2018	2006-2022	1996-2022
Effort	Targeted potting and netting effort not available	No	Targeted potting and netting effort not avail-able	Yes	2007-2022
LPUE	No	No	No	Recent	2007-2022
DPUE	No	No	No	Recent	
Size frequency data	Yes. At least recent i.e. 2004-2013 maybe much longer series	No	Few data from some periods	Recent	2004-2022
Others	No	No			
Analytical assessment methods					
LCA	No	No	No	No	No
Production	No	No	No	No	No
Change in ratio	No	No	No	No	Yes
Depletion methods	No	No	No	No	No
Others	No	No	No	No	No
Data sources					
Surveys			Yes (1986-1996)	Yes (1985, 2003 & 2009)	
Larval	No	No	Yes	No	
Juvenile index /biomass	Possibly	No	No	No	
Adult index/biomass			Yes	No	yes 2004-2022
Non target surveys				No	
Commercial					
Observer/self reporting/reference fleet	No	No	No	Recent	No
Size frequency data	Yes	No	Few data from some periods	Recent	No
Logbooks	No	No	Yes	Yes. From reference fleet	Yes
Tag returns	No	No	No	No	No
VMS	No	No	Yes	Yes (2005-2007)	No
Electronic logbooks	No	No	For some vessels	No	No
Others	No	No	Recruitment Study	No	No
Biological parameters					
M			No	No	No
Growth data			Few data from some periods	No	No
Fecundity			Few data from some periods	No	No
Size at maturity			No	No	No
Others					No
Analytical assessment outputs					No
Biomass	No	No	No	No	No
Spawning stock	No	No	No	No	No
Recruitment	No	No	No	No	No
Fishing mortality	No	No	No	No	

Table A5. Stock summary for *Homarus gammarus* by country, including summaries of fishery indicators, analytical assessments and biological parameters.

	England	Scotland	France	Norway	Northern Ireland	Ireland	Jersey	Wales
Number of stocks	5	12	8			4	Jersey	
Stock areas (cross reference to map)	Northumberland Durham	Clyde		Skagerrak	37E3, 37E4, 38E4, 39E3, 39E4	Malin		
	Yorkshire Humber	East Coast		West-Norway		SW Ireland		
	East Anglia	Hebrides		Mid-Norway		SE Ireland		
	Southeast and South coast	Mallaig				N Irish Sea		
	Southwest	North Coast						
		Orkney						
		Papa						
		Shetland						
		South East						
		South Minch						
		Sule						
		Ullapool						
Indicator								
Landings	1983-2022	1974-2022	2000-20222	1815-2022 (commercial only)	2006-2021	1996-2022	2007-2022	2010 - 2022
Effort	1983-2022		2000-2022	1928-2022	2006-2021		2007-2022	2010 - 2022 Only Engine power and departure and landing date, no data on pot numbers
LPUE	Yes		2000-2022	1928-2022	2006-2021	Yes. early 2000's-onwards: Self-sampling reference fleet	2007-2022	no
DPUE	No		no		2010-2022	Yes. Early 2000's-onwards from Self-Sampling reference fleet	2004-2022	no
Size frequency data	Yes	1974-2022	2010-2022	1928-2022	2010-2022	2008-onwards (earlier in some areas)	2004-2022	1983 - 2022, collection method not standardised
Others						V-Notched and Oversized per unit of effort (VPUE,OPUE) (2013-onwards)		
Analytical assessment methods								
LCA	Yes (length-based VPA)	Yes	no	No		No	No	CEFAS occasionally completes for Wales
Production	No	No	Yes(in progress)	Yes (test stage)		No	No	no
Change in ratio	No	Yes	no	No		No	Yes	no
Depletion methods		No	no	No		No	No	no
Others	LPUE selected logbook vessels				Length-based indicator			
Data sources								
Surveys								
Larval	No	No	yes	No	Some information through genetics	No	No	no
Juvenile index /biomass	No	No	in progress	No	No	No	Yes	no
Adult index/biomass	No	No	no	No	No	No	Yes	no

	England	Scotland	France	Norway	Northern Ireland	Ireland	Jersey	Wales
Non target surveys	No	No	no	No	bycatch recorded in all AFBI surveys	No	No	no
Commercial								
Observer/self reporting/reference fleet	Selected logbook vessels from 1985	Observer	observer and self-reporting	Self reporting	Observer	Yes(Observer, self-reporting and reference fleet)	Reference fleet	no
Size frequency data		Yes	yes	Yes	Yes 2010-2022	Yes(Observer)	Yes	1983 - 2022, although collection method is not standardised and we are working on data quality/comparability over time
Logbooks		Yes (EU logbooks)	yes	Yes	Yes Monthly Shellfish Returns (weekly in Strangford Lough)	Yes (EU logbooks >10m; sales notes <10m)	Yes	yes
Tag returns		No	yes	No	Yes	Yes	No	no
VMS	Yes	Yes (boats > 12m)	yes>12m	No	Yes boats > 12m; boats in Strangford Lough	Yes, only boats >12m	Yes (>12m)	yes, all vessels
Electronic logbooks	No	No	yes>12m	Yes	No	No	Yes	yes
Others								
Biological parameters								
M	0.15	0.1	0,1-0,2		0.1	No		No
Growth data		K_m=0.11 ; $Linf_m$=173.4; K_f=0.13 ; $Linf_f$=150;			Km=0.072 ; Linfm=149.4; Kf=0.074 ; Linff=146.5	k=0.12; Linf=172		No
Fecundity						Tully *et al.,* 2001		In prep - available on request
Size at maturity		~80 mm	92-93 mm CL< L50 <103mm CL		75	Coleman *et al.,* 2022		Coleman *et al* 2023, Hold *et al* 2022 (onset = 73-75 mm; physiological =83 - 88 mm; functional = 90 mm)
Others		Terminal F=0.5	% of berried females by size		LF=MM=102.5, LoptM=99.3, Linf90M=134; LF=MF=101.85, LoptF=97.6, Linf90F=132;	Size-Weight relationship		size-weight (Bangor University data)
Analytical assessment outputs								
Biomass	Yes	Yes	in progress for some areas	No		No	No	no
Spawning stock	Yes	No	no	No		No	No	no
Recruitment	No	No	no	No		No	No	no
Fishing mortality	Yes	Yes	in progress for some areas	No		No	No	no

Table B1. Management measures table by country for *Cancer pagurus*.

Area	Central North Sea UK	Southern North Sea UK	Eastern Channel UK	Western Channel UK	Celtic Sea UK	Irish Sea UK	Norway	Scotland UK	Jersey	Northern Ireland UK	Ireland	Sweden	Western Channel / Bay of Biscay France	Wales UK
Management measure														
Licensing	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	MSAR/EU	No	MSAR/EU	UK fishing licence required	UK fishing licence required	General fishing licence	Licenses for fisherman; not for recreational fishery	yes	Shellfish entitlement
Limited Entry	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	Yes for <10m	No	Yes for <10m		No	No	yes, for fisherman and recreational fishery	Yes	No
Closed seasons	No	Generally no but regional ban on white footed crab Nov-Jun	No	No	No	No	No	No	No	No	No	No	No	No
Days at sea	No	No	No	No		No	No	Yes Under EU Regulations the annual fishing effort of UK vessels over 15 m participating in the brown crab fishery is restricted to 702,292 KW days in ICES areas V and VI and 543,366 KW days in ICES are VII.	No	No	Yes Limit on Kw.Day (465,000 kw.days) for vessels >15m in ICES Division VI Limit on Kw.Day (40,960 kw.days) for vessels >15m in ICES Division VII Limit on Kw.Day (63,198 kw.Day) for vessels >10m in Biological Sensitive Areas (BSA's) in ICES Division VII	No	There is limitation for days at sea, but the French fleet never reach the threshold.	No
Closed areas	No	No	No	No	Lundy	No	Yes (no trap fishing in lobster MPAs)	Fishing with creels is prohibited in certain areas (Article 5 of The Inshore (Prohibition of Fishing Methods) (Scotland) Order 2004).	All extractive activities are excluded from the Portelet No Take Zone (~0.5km2. Parlour pots are banned at two offshore reefs.	Potting prohibited in certain MPA's	No	marine protected areas, targeting lobster	There are some closed areas for crustaceans along the French coat call : « Cantonnement »	No
Others														
Minimum size	130mm CW (140mm north of 56N)	115 and 130mm CW	130mm in Southern Bight and 140mm CW	Various/regional 140mm - 150mm(CRH) 140-160mm (CRC)	Various/regional 130mm - 150mm(CRH) 130-160mm (CRC)	Various/regional 130mm - 140mm(CRH) 130-140mm (CRC)	13 cm (11cm southern Norway from Swedish border to Rogaland (59°30'N)	150mm CW (except Shetland where 140mm CW applies)	150mm CW	150mm	140mm CW from 2019 onwards (130mm CW before)	No	140mm CW north 48°, 130mm south 48° but this rule should change in few time and 150 mm in the bay of Granville for one year now.	140 mm
Maximum size	No	No	No	No	No	No	No	No	None	No	No	No	no	No

Area	Central North Sea UK	Southern North Sea UK	Eastern Channel UK	Western Channel UK	Celtic Sea UK	Irish Sea UK	Norway	Scotland UK	Jersey	Northern Ireland UK	Ireland	Sweden	Western Channel / Bay of Biscay France	Wales UK
Berried female legislation	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	no	No
Soft crabs	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Consultation held 2022; DAERA to amend legislation to ban landing soft shelled crab	No	No	Not banned but there is no market then landing is considered as null.	Banned except for bait
Single sex fishery	No	No	No	No	No	No	No	No	No	No	No	No	no	No
Claws or parts	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears.	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears. No parts regional	Claws <1% by wt. or <75kg for other gears.	No	Claws <1% by wt. or <75kg for other gears. No parts regional	% and max weight	Prohibited under The Edible Crabs (Conservation) (Amendment) Regulations (Northern Ireland) 2021	Claws <1% by wt. or <75kg for other gears	Claws <1% of the weight of the total catch	Claws <1% by wt. or <75kg for other gears. No parts regional	Banned
Use as bait	Regional	Regional	No	No	No	No	Yes (mainly cleaner wrasse and whelk fisheries)	Regional	No laws	Will be linked in with soft crab legislation	Yes (mainly whelk fishery)	No	no, only fishmongers sell the dead crabs in the storage tanks	Yes, especially for whelk
Vessel size	Regional <12 and 16m inside 6nm	Regional <16 and 17m	Regional <14 and 17m	Regional <11, 15, 24 and 16.46m	Regional <12, 13.7, 14, 15 and 21m	< 31.35m inside 4nm	No	Regional	No	No	No	No	no	none
Vessel power	No	No	No	No	No	No	No		No	No	No	No	no	none
VMS	>15m	>15m	>15m	>15m	>15m	>15m	>15m	>12m	>12m	>12m and all vessels within Strangford Lough	>12m		Yes >12 meters	Yes, all vessels
Log book returns	Yes	Yes	Yes	Yes	Yes	Yes	Yes (phased in for boats <15m from 2022)	Yes	Yes	Yes Strangford Lough weekly, rest monthly	Yes Over 10m	Yes	yes	Yes, plus catch app for <10m
Others														
Trap limits	Yes	No	Regional	No	No	No	No	No	1000 per boat/size dependent	No	No	unlimited for fisherman, limited to 6 pots or 180 m net for recreational fisherman	yes	No
Trap size	No	No	No	No	No	No	No	No	No	No	No	No	yes	No
Escape vents	No	Yes Regional and gear specific	Yes Regional and gear specific	Yes Regional and gear specific	Yes Regional and gear specific	Regional	Yes	No	Yes (on parlours)	No	No	Yes, 15 cm, closed with a 3mm thick untreated cotton thread	in some place	Not required

Area	Central North Sea UK	Southern North Sea UK	Eastern Channel UK	Western Channel UK	Celtic Sea UK	Irish Sea UK	Norway	Scotland UK	Jersey	Northern Ire-land UK	Ireland	Sweden	Western Channel / Bay of Bis-cay France	Wales UK
Biodegradable panels	No	No	No	No	No	No	Yes (de-gradable threads)	No	No	No	No	Yes	no	not re-quired
Marked gear	Regional	Regional	Regional	Regional	Regional	Regional	Yes	Regional	Yes	Not standard-ised	No	Yes	yes	Shellfish entitlement

Table B2. Management measures table by country for *Chionoecetes opilio*.

Area	West coast of Greenland Greenland	Newfoundland Canada	Southern Gulf Canada	Barents Sea Norway	Barents Sea Russia^
Management measure					
Licensing	Yes	Yes	Yes	Yes	No
Limited Entry	Yes for < 75 Brt	Yes (no new licences available)	Yes	No	No
Closed seasons	No	Yes	Yes	Yes	No
Days at sea	No	No	No	No	No
Closed areas	Yes	Yes	Yes	No	No
Others		Dockside Monitored Landings, Soft-shell protocols, Trip Limits	Soft crab control		
Minimum size	100 mm CW	95mm CW	95mm CW	95mm CW	No
Maximum size	No	No	No	No	No
Berried female legislation	Yes - prohibition to land females	Yes - prohibition to land females	Yes - prohibition to land females	Yes - prohibition to land females	No
Soft crabs	Yes	Yes	Yes - prohibition to land soft crab		
Single sex fishery	Yes	Yes	Yes	Yes	Yes
Claws or parts	no	no	No	No	No
Use as bait	Squid	Squid / Herring	Mackerel, Herring, Squid	mostly squid	Herring
Vessel size	Regional <10m	Various fleet sectors (<40', 40-64'11", 65-89'11")	65 fts or less		49.6-54.8 m
Vessel power	No	No	No		700-1700 hps
VMS		Yes	Yes	Yes	Yes
Log book returns	Yes	Yes	Yes	Yes	No
Others		100% dockside monitored landings	100% dock side landing monitoring & at-sea observer coverage at approximately 20%		
Trap limits	No	Yes	Yes (the number varies depending on the area from 50 to 150/ licence), Area 19 has total trap number at 1699	Yes	No
Trap size	Yes (mesh size 1400mm)	Yes (135mm)	Yes (volume should not exceed 2 cubic meter) and maximum and minimum mesh sizes at 65 and 75 mm	No	No
Escape vents	No	No	No but see below	No	No
Biodegradable panels	No	Yes	Biodegradable twine	No	
Marked gear	Regional / overseas trade	Yes	Yes		

^ No updates provided by these countries since the previous WGCRAB report (ICES, 2021)

Table B3. Management measures table by country for *Paralithodes camtschaticus*.

	Barents Sea Norway		Barents Sea Russia^
Management measure			
Licensing	Yes		Yes
Limited Entry	Yes		Yes
Closed seasons	Yes (April)		Yes
Days at sea	No		No
Closed areas	No		Yes
Others			
Minimum size	130mm for male and female		150mm
Maximum size	No		No
Berried female legislation	No		Yes - prohibition to land females
Soft crabs			
Single sex fishery	No		Yes, only males
Claws or parts	No		Sections by different weight
Use as bait	Herring		Herring
Vessel size	6-22 m		49.6-54.8 m
Vessel power			700-1700 hps
VMS	Yes		Yes
Log book returns	Yes		No
Others			
Trap limits	Yes		Yes
Trap size	Yes		Yes
Escape vents	Yes		No
Biodegradable panels	No		Yes
Marked gear	Yes		No

^ No updates provided since the previous WGCRAB report (ICES, 2021)

Table B4. Management measures table by country for *Maja brachydactyla*.

	England UK	**France**	**Ireland**	**Jersey**	**Wales UK**
Management measure					
Licensing	Yes	Yes	Yes	UK fishing licence required	Shellfish entitlement
Limited Entry	<10m	Yes	No		No
Closed seasons	No	No	No	Yes (mid sept-end Oct)	No
Days at sea	>15m in Celtic Sea	No	ICES Area V, VI Vessels >15m, are limited to 465,000 kw.days; ICEAS Area VII, Vessels >15m are limited to 40,960kw.days; ICES Area VII (Biologically Sensitive Area), Vessels >10m are limited to 63,198 kw.days	No	No
Closed areas	No	Yes	No	All extractive activities are excluded from the Portelet No Take Zone (~0.5km2. Parlour pots are banned at two offshore reefs.	No
Others		No licence for trawlers and dredgers			
Minimum size	120mm CL females; 130mm for males	120 mm CL, male and female	125 mm CL Females; 130mm CL for Males	120mm CL	120 mm Female, 130 mm Males (CL)
Maximum size	No	No	No	None	No
Berried female legislation	No	No	No	No	No
Soft crabs	No	No	No	Yes	No
Single sex fishery	No	No	No	No	No
Others					
Vessel size	Regional	No	No	No	No
Vessel power	No	No	No	No	No
VMS	>15m	>12m	>12m	>12m	Yes, all vessels
Log book returns	Yes	Yes	Yes for >12m	Yes	Yes, includes Catch App <10 m
Others		National log book for vessels under 12 m	Sentinel Vessel Programme Data		
Trap limits	Regional	Yes	No	1000 per boat/size dependent	No
Trap size	No	No	No	No	No
Escape vents	Regional and gear specific	No	No	Yes (on parlours)	No
Biodegradable panels	No	No	No	No	No
Others	No	yes, rigid and minimum of 14 cm di-ameter	No		
Marked gear	Regional	Yes for pots	No	Yes	
Gillnet limits		Yes	No	Yes	
Gillnet mesh		Yes	No	Yes	

Table B5. Management measures table by country for *Homarus gammarus*.

	England UK	Scotland UK	France	Norway	Jersey	Northern Ireland UK	Ireland	Wales
Management measure								
Licensing	Yes	MSAR/EU	Yes (if lobster landing>10 % of the total landings)	Yes (mandatory registration)	UK fishing licence required	UK fishing licence required	General fishing licence	Shellfish entitlement
Limited Entry	Yes	Yes for <10m	yes	No		No	No	No
Closed seasons	No	No	no	Yes (Oct-Nov south of 62°N, Oct-Dec rest of country)	No	No	No	No
Days at sea	No	No	no	No	No	No	No	No
Closed areas	MCZ restrictions (regional)	Fishing with creels is prohibited in certain areas.	In some areas, there are some no take zones specifically for crustaceans	Yes (>50 local lobster MPAs)	All extractive activities are excluded from the Portelet No Take Zone (~0.5km2. Parlour pots are banned at two offshore reefs.	Potting prohibited in certain MPA's	No	No
Others						funded v-notching and genetics schemes		
Minimum size	87mm CL national, 90mm within 6 miles of coast (Devon, Cornwall, Isle of Scilly)	90mm CL (Shetland Islands, Orkney Islands, Outer Hebrides and West Coast from Cape Wrath to 55°N) 87mm CL rest of Scotland	87 mm CL in all regions excepted in North Eastern Channel areas where it is 90 mm CL	250mm TL	87mm CL	87mm	87mm CL	90 mm CL
Maximum size	No	Yes - for females only 145mm CL in all areas except Shetland and Orkney where 155mm CL applies	no, only some discussions	320mm TL	None	No	127mm CL	No
Berried female legislation	Yes (regional)	No	no	Protected	No	No	No	No
Soft crabs	Yes	No	no	No	No	No	No	No
Single sex fishery	No	No	no	No	No	No	No	No
Claws or parts	Limits on percentage/ quantity caught (regional)	Illegal to land 'V'-notched lobsters, or mutilated animals. Lobsters can only be retained on board or landed whole.	No laws	No	No laws	Prohibited to land v-notched lobsters or lobsters with a damaged tail.	Illegal to land V-Notched lobsters	No claws, no mutilated animals, v-notched
Use as bait		No	no	No	No laws	No	No	No
Vessel size	Yes (regional)	No	no	No	No	No	No	no
Vessel power		No	no	No	No	No	No	no
VMS	>12m	>12m	>12m	>15m	>12m	>12m and all vessels within Strangford Lough	>12m	Yes, all vessels
Log book returns	Yes	Yes	yes	Yes (phased in for boats <15m from 2022)	Yes	Yes Strangford Lough weekly, rest monthly	>10m	Yes, includes Catch App <10m
Others								
Trap limits	Yes (regional)	No	yes	10 (100 for commercial fishers)	1000 per boat/size dependent	No	No	no
Trap size	No	No	yes (entrance > 140 mm for the diameter)	No	No	No	No	
Escape vents	Yes (regional)	No	In some areas for classical pots and Yes (on parlours)	Yes	Yes (on parlours)	No	No	
Biodegradable panels	No	No	no, but discussions for parlour pots	Yes (degradable threads)	No	No	No	
Marked gear	Yes (regional)	Regional	yes	Yes	Yes	Not standardised	No	
Entrance size	No	No	yes, rigid and minimum of 14 cm diameter		Yes - parlour pots		No	
Parlour pot	No	No	Yes (regional)		Prohibited in some areas			

Table C1. Landings (tonnes) of *Cancer pagurus* by country.

Year	England	Wales	Scotland	France	Norway	Ireland	Jersey	Northern Ireland	Sweden
1990			4 282	6 076	1 374				70
1991			5 485	5 310	1 462				90
1992			4 648	5 583	1 316				97
1993			3 820	5 896	1 641				95
1994			4 759	6 086	1 781				161
1995			6 092	6 823	1 806				105
1996			5 528	6 527	1 889		495		88
1997			7 470	7 000	2 205		523		79
1998			8 021	6 490	2 984		521		93
1999			7 437	6 087	2 836		473		124
2000	12 363		9 650	5 182	2 890		440		129
2001	13 013		8 458	5 513	3 478		447		137
2002	11 973		7 874	5 963	4 344		524		148
2003	13 349		7 525	6 327	4 944	10 864	540		161
2004	10 825		6 761	7 813	5 248	12 982	541		170
2005	8 484		8 332	6 259	5 671	9 011	438		165
2006	11 043		10 430	5 423	6 205	8 467	349		135
2007	12 074		11 919	6 178	8 515	6 313	412		153
2008	11 697		9 336	6 416	5 295	5 732	481		151
2009	11 001		9 466	4 353	4 971	4 001	361	1746	177
2010	11 902		10 857	5 487	5 773	6 481	409	2034	216
2011	12 089		11 859	5 690	5 319	5 788	434	2118	204
2012	13 844		10 890	5 990	4 982	4 425	474	2513	202
2013	13 804		10 891	5 570	5 241	5 159	431	2571	223
2014	16 330		12 306	5 901	4 629	6 239	383	2418	212
2015	12 838	385	11 087	4 744	4 743	5 773	303	2325	224
2016	15 839	437	12 141	4 668	4 926	8 013	346	2611	209
2017	14 498	707	11 600	4 242	4 924	7 867	300	3215	251
2018	14 607	676	10 467	3 764	5 850	7 111	287	2993	247
2019	14 870	462	9 813	3 330	5 371	6 738	171	2492	274
2020	12 121	253	6 634	2 720	4 710	4 765	127	1583	273
2021	12 487	217	6 411	2 190	5 164	6 114	143	1486	290
2022	11 609	192	6 160	1 700	2 356*				

*Provisional

Table C2. Landings (tonnes) of *Chionoecetes opilio* by country.

Year	Canada	Greenland	Norway	Russia^	France
1990	26 233				
1991	35 295				
1992	37 232				
1993	47 819				
1994	60 662				
1995	65 491	997			
1996	65 078	563			189
1997	69 934	3 214			368
1998	73 097	2 094			354
1999	95 145	4 982			589
2000	93 281	10 521			550
2001	95 026	15 139			485
2002	106 395	11 174			139
2003	96 341	7 179			83
2004	102 791	6 295			159
2005	93 895	4 213			157
2006	89 454	3 305			191
2007	90 363	2 189			166
2008	93 509	2 354			123
2009	96 801	3 191			169
2010	83 894	2 363			236
2011	84 119	2 015			242
2012	92 958	1 983	2		325
2013	98 072	2 162	189	62	251
2014	96 313	2 157	1 881	4 104	100
2015	93 687	2 021	3 105	8 895	28
2016	82 409	1 506	5 406	7 520	5
2017	92 571		3 101	7 780	21
2018	67 356		2 812	9 728	86
2019	71 762		4 049	9 840	123
2020	69 697		4 387		178
2021	75 969		6 861		344
2022	93 992		7 959		320

^ No updates provided since the previous WGCRAB report (ICES, 2021)

Table C3. Landings (tonnes) of *Paralithodes camtschaticus* by country.

Year	Norway^	Russia^^
1994	11 000	22
1995	11 000	9
1996	15 000	24
1997	15 000	63
1998	25 000	90
1999	37 500	143
2000	37 500	113
2001	100 000	300
2002	100 000	900
2003	200 000	1 950
2004	280 000	1 105
2005	1 223	3 021
2006	1 041	9 389
2007	1 267	9 953
2008	5 199	8 823
2009	5 628	6 142
2010	1 905	3 787
2011	1 782	3 698
2012	1 438	5 209
2013	1 321	5 531
2014	1 695	5 995
2015	2 175	6 380
2016	2 639	8 300
2017	1 945	9 285
2018	2 312	9 197
2019	1 727	
2020	2 081	
2021	2 122	
2022	1 415*	

*Provisional

^Norway: 1994-2004: Number of individuals

^^ No updates provided since the previous WGCRAB report (ICES, 2021)

Table C4. Landings (tonnes) of *Maja brachydactyla* by country.

Year	France	Ireland	Scotland	Jersey
1990				
1991				
1992				
1993				
1994				
1995				
1996				383
1997				162
1998				160
1999				175
2000				172
2001				236
2002	3 618			270
2003	3 692			233
2004	3 876	182		223
2005	3 744	146		163
2006	4 287	151	0.7	129
2007	4 297	66	0.1	106
2008	4 074	148	3.1	179
2009	2 547	443	6.0	177
2010	3 351	414	3.1	173
2011	3 925	303	1.2	144
2012	3 451	402	1.7	108
2013	3 321	228	0.2	81
2014	4 552	137	0.1	87
2015	4 794	193	0.7	94
2016	5 822	161	0.1	120
2017	6 579	143	0.6	201
2018	7 171	119	0.2	285
2019	7 253	425	0.2	307
2020	7 546	451	1.1	203
2021	8 025	477	10	226
2022	6 778		8.6	

Table C5. Landings (tonnes) of *Homarus gammarus* by country.

Year	England	Wales	Scotland	Ireland	France	Jersey	Norway^	Northern Ireland
1990			769				33	
1991			687				35	
1992			513				28	
1993			369				28	
1994			457				30	
1995			565				34	
1996			453			164	30	
1997			653			166	37	
1998			638			157	45	
1999			509			153	59	
2000	786		411			128	52	
2001	776		289			130	40	
2002	832		341		294	157	42	
2003	1 008		353		348	167	52	
2004	921		404	657	339	167	52	
2005	910		409	855	324	139	58	
2006	1 587		711	646	388	131	62	
2007	1 700		890	613	475	155	57	
2008	1 695		915	302	444	163	44	
2009	1 640		953	498	329	177	50	65
2010	1 531		1 100	423	863	225	59	65
2011	1 845		1 219	470	802	257	58	75
2012	1 888		1 132	250	535	237	63	80
2013	1 821		1 026	244	500	223	58	80
2014	2 020		1 208	367	560	234	52	103
2015	1 700	184	1 042	445	530	254	46	107
2016	1 811	173	1 151	363	560	239	54	85
2017	1 945	164	1 214	402	691	231	48	85
2018	1 625	214	1 220	415	710	190	50	77
2019	1 738	244	1 190	345	692	155	41	86
2020	1 495	164	1 089	488	649	112	45	77
2021	1 784	157	1 145	438	610	116	53	86
2022	1 816	157	1 134	619	600			

^ Commercial landings only